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THE
MAGNETIC ATLAS,
OR
VARIATION CHARTS
OF THE WHOLE
TERRAQUEOUS GLOBE;

COMPRISING A
SYSTEM
OF THE
VARIATION & DIP OF THE NEEDLE,
BY WHICH
THE OBSERVATIONS BEING TRULY MADE,
The Longitude
MAY BE ASCERTAINED.

THE THIRD EDITION WITH ADDITIONS.

BY JOHN CHURCHMAN,
Fellow of the Russian Imperial Academy.

NEW-YORK:
PRINTED FOR THE AUTHOR,
AND SOLD BY GAINE & TEN EYCK, NO. 148, PEARL-STREET.
1800.

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BRITISH MUSEUM

PREFACE.

IT appears probable, that one of the principal cauſes, why more uſeful diſcoveries are not made, is the fear of ridicule, which is ſometimes the lot of thoſe who promulgate new opinions, and attempt new experiments. A deſire of avoiding the ſarcaſms of ignorance and malevolence, may ſuppreſs many uſeful inventions; yet we find ſome gradually preſs forward; and although, for want of encouragement, an hundred probable ſchemes may ſink in oblivion, there will ever be ſome of ſuch magnitude, in the minds of their own inventors, that they will burſt into day, and either go off in vapour, or remain permanent lights.

In a ſituation of ſpeculative enquiry, I confeſs I had for ſometime continued, but in the beginning of the year 1787, I riſked a declaration of my opinions before the public, apprehending I had formed a plan of much importance to navigation, and confiding in their generoſity to give it a candid reception, which, in a great meaſure, I was ſo fortunate as to obtain: now, as the firſt principles ſeem to be univerſally admitted, I have the more reaſon to hope for further indulgence towards the preſent publication. If any imperfections ſhould be found in the arrangement, the reader is reſpectfully ſolicited to excuſe the defect; and I truſt, under a conviction that this work will do no injury to mankind, it may at leaſt obtain for me their forgiveneſs, if not their thanks for my intention of rendering them a ſervice. And yet, I muſt acknowledge, that, in purſuing this ſubject, I conſidered it alſo as an object of emolument; and with this view have accepted the invitation held out by many governments, with promiſes of a generous reward, to engage perſons in the public ſervice.

In the following treatiſe I ſhall proceed to deſcribe, in a more particular manner, the elements of a ſyſtem, which, if the obſervations can always be truly made, I apprehend, attains to the actual and complete diſcovery of the longitude. This indeed is a ſubject which, when attempted, has ſometimes excited a ſmile, yet I riſk that for the public good.

The variation of the compaſs, and its heretofore uncertain laws, have long engaged the attention of philoſophers. Why it ſhould change, at one time quick, at another time ſlow, now become ſtationary, and then retrograde, has puzzled the enquirer. Theſe varieties have long been ſubjects of obſervation; yet I have never heard that any regular ſyſtem has hitherto been publiſhed, that would rationally account for, or foretel, the future movements of that wonderful phenomenon, the magnetic influence.

On the contrary, the modern writers on this ſubject, ſome of whoſe names are mentioned in the introduction, have ſignified that all former endeavours to eſtabliſh a theory have proved inſufficient; nevertheleſs, it has long been ſuppoſed that if all the true principles of the variation were known, nothing ſhort of a diſcovery of the longitude would be the natural conſequence.

The Egyptians, by reaſon of the overflowing of the Nile, which either waſhed away their landmarks, or covered them with mud, brought geometry into a ſcience, and honoured its profeſſors. From meaſuring the earth, they ſoon began to meaſure the heavens. If from Egypt this kind of knowledge was brought to Greece, by degrees it ſpread over Europe, and the great monuments of learning continuing unſhaken to the preſent day, demonſtrate the wiſdom of the ancients in chuſing geometry for their foundation.

Circumstances in the preſent caſe are ſomewhat different from thoſe in Egypt; from the firſt ſettlement of the United States of America to the preſent time, the lands have been laid out on geometrical principles, and the courſes of the boundary lines run by the aſſiſtance of the magnetic needle, as if there was no variation of the variation. In proceſs of time, when the lands came to be reſurveyed, the ſame courſes and diſtances would not cover the ſame ground, without an allowance proportioned to the ſituation of the place, and the date of the original ſurvey. The great number of tracts of land laid out from time to time throughout the country afford the means of aſcertaining the nature of the change of the variation.

To arrive at a competent knowledge of the laws of the magnet, an univerſal ſet of obſervations ſeemed abſolutely neceſſary. In Europe records of the variation have been handed down at thoſe few places, where learned ſocieties are eſtabliſhed. The want of a ſufficient number of ſuch records have been much lamented by thoſe who have applied themſelves to this ſubject; and the ſet could not be complete without a ſeries of obſervations in America. In that country a certain ſyſtem, by which the proper allowance could be made, by degrees, became a great national object, independent of its extenſive uſe in Navigation, and the confuſion ariſing from the want of it has occaſioned many diſputes and law-ſuits.

In purſuance of an appointment to a public office under government in that country, the duty of which ſometimes required the ſettlement of ſuch diſputes, I was led to pay attention to this ſubject; in this reſpect I ſtepped not out of the line of my profeſſion.

The date of each original ſurvey being recorded, there was nothing to do but determine the latitude and longitude of many tracts of land, and the preſent courſes of the lines, in order to find what the variation had been at the firſt ſurvey.

Besides, in collecting materials for a map which I publiſhed, moſtly from actual ſurveys, including the maritime parts of Weſt Jerſey, Pennſylvania, Maryland, Virginia, and all the Delaware State; as theſe ſurveys were made from time to time by the magnetic needle, without allowance for variation, I had to make calculations, that the map might be conſiſtent with the truth.

If the ſeveral reſpectable characters in Europe, who have applied themſelves to this ſubject, have not ſucceeded in the attempt, it is fair to ſuppoſe that it was from the want of ſufficient data: with helps, which ſeemed out of their reach, it may not perhaps be deemed preſumptuous in me to renew the attempt, though others have failed.

The introduction of a number of new terms being abſolutely neceſſary, as they are accompanied with definitions, this ſtep will be excuſable.

Many reports and letters have been received by the author from learned ſocieties and individuals; a few only of theſe will be found in the Appendix. To publiſh the whole might appear oſtentatious.

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INTRO-

INTRODUCTION.

HISTORY OF MAGNETIC DISCOVERIES.

IT ſeems to be a fact well authenticated, that the attractive quality of the Magnet has been known in the moſt remote ages; a number of the earlieſt writers, ſuch as Homer, Pythagoras, and others make mention thereof. According to Pliny and Nicander, it took its name from Magnes, a Herdſman, who having his ſhoes and ſtaff armed with iron, and reſting himſelf on a quantity of loadſtone on Mount Ida, he could not eaſily remove his feet or lift up his ſtaff; he ſoon perceived that the attractive virtue was in the ſtone. Others call it Lapis Heraclaeus, from Heraclea, a city of Magneſia, where they ſuppoſe it to have been found. Thales and Anaxagoras ſay that the magnet hath life, whereby it attracteth iron. Plato thought this attraction to be divine, and ſome that there is a ſympathy between the magnet and iron, as between male and female, as Orpheus and Lucretius have ſung.

ALTHOUGH theſe early writers were acquainted with the loadſtone, they muſt have been ignorant of its polarity:

yet

yet like many of the moderns, they might have amuſed themſelves with its attractive quality.

Nevertheless it appears from Du Hald's General Hiſtory of China, and from other authorities, that the Magnetic Needle was known to that nation 1040 years before Chriſt. However, many European writers have each claimed for their own particular country the honour of inventing the Mariner's Compaſs, others have been ſatisfied in naming the perſons who firſt introduced it into Europe, and improved upon the invention.

The apoſtle Paul, in the account of his voyage to Rome, by ſome Engliſh tranſlators is made to ſay, from Syracuſe we *ſet* a compaſs, and came to Rhegium. Theſe learned divines could hardly mean a Mariner's Compaſs, becauſe no ſuch thing is mentioned in the original.

Sir Roger L'Eſtrange alſo, in the tranſlation of that Chapter of Seneca's Morals which treats on a Happy Life, in ſpeaking of a careful ſeaman, ſays "he conſults his compaſs, and keeps aloof from thoſe places that are infamous "for wrecks and miſcarriages." Whoever takes the trouble to examine the original will be convinced of the unwarrantable liberty taken by the tranſlator.

Guyot de Provens, a French poet, who wrote about the year 1180, makes expreſs mention of the loadſtone and the compaſs; and their uſe in navigation is alſo hinted at, notwithſtanding Dr. Gilbert informs us that Paulus Venetus (or Marco Paulo, a Venetian) brought this invention from China to Italy in the year 1260. Be this as it may, the northern nations of Europe appear to have been acquainted with it ſoon after, for the year 1266 is remarkable for the death of the Swediſh count *Byrgeris*, who by the Swedes is called Duke Pontana Byrger Jarl. Sturla celebrated his memory in a poem conſiſting of twelve verſes, and when he attended the king to the boundaries of the kingdom, he produced this poem in an aſſembly of the ſtates; and, as a reward for his genius, he was preſented with a Mariner's Compaſs. See Torfaeus (Thormodus) Hiſtoria Rerum Norvegicarum, 4 tom. folio 345. All theſe accounts are prior to the time when this invention has generally been ſuppoſed to be firſt introduced into Europe; for it has been ſaid that John or Flavio de Goia, or Gioia, or Gioja, or Giova, or Gira, invented this inſtrument in the year 1300 or 1302.

For ſome time after the Mariner's Compaſs was made uſe of in Navigation, it was thought the needle at all places pointed due north; but the celebrated Chriſtopher Columbus, during his firſt voyage to America, diſcovered the variation on the 14th of September 1492, as his ſon Ferdinand aſſerts in an account of his father's life, written originally in Spaniſh, and printed in Italian, at Venice, in the year 1571, his mutinous crew concluding the needle had loſt its polarity, they were afraid of not finding their way to Europe.

It is true ſome have attributed this diſcovery to Sebaſtian Cabot, a Venetian, who is ſaid to have made it in the year 1500.

The remarkable property of the dipping needle was diſcovered, in the year 1576, by Robert Norman, a mathematical inſtrument maker, in the ſuburbs of London. His book "*The new Attractive,*" gives an account of this diſcovery. He tells us that, "having made many Compaſſes, and "always balancing the needles before he touched them with "the magnet, he found continually that, after he had touched them, the north point would incline downwards, under "the horizon, inſomuch that the fly (or card) of the compaſs, which before was equal, he was ſtill conſtrained to "put ſome ſmall piece of wire on the ſouth part thereof, to "counterpoiſe it." He then communicated his obſervations to ſome of his literary friends, who adviſed him to frame an inſtrument, and make an exact trial what would be the greateſt angle it would make with the horizon; and he found the inclination (or dip) when the diſcovery was made, to be 71° 50′, or thereabouts.

In Norman's "New Attractive" and in a diſcourſe on the variation of the Compaſs by his friend and patron William Borough, Comptroller of the Navy to Queen Elizabeth, both publiſhed in 1581, and bound together, they ſay "the "variation is 11° 15′ eaſt;" but this obſervation was made by the Comptroller in the year 1580, at Lime-Houſe. The altitudes of the ſun were taken by him to each degree of a quadrant, both before and afternoon, from 17° to 25°, being the mean of nine ſeveral obſervations, and at every altitude turning his compaſs to the ſun, obſerved the degree and parts cut thereby; then comparing the magnetical azimuths made in the forenoon with thoſe in the afternoon, anſwerable to the ſame ſolar altitudes, the half of the difference gave the variation. The works of Norman and Borough were corrected, amended, and reprinted in the year 1585, and as the variation was decreaſing, it muſt neceſſarily have been much leſs that year; but as they ſtill ſay the variation, was 11° 15′ eaſt, it is clear they had no ſuſpicion it was ſubject to alteration, or they would have obſerved it again, and have publiſhed the true variation as it muſt have been in the year 1585. In the next century William Borough is cenſured, for making no allowance for refraction, by Profeſſor Gellibrand, who made a new calculation from the obſervations of Borough, and, after allowance for refraction, he found the variation for the year 1580 to have been only 11° eaſt.

THE magnetic variation was taken under conſideration by Prince Maurice, of Naſſau, lord high admiral of the United Provinces, of the Low Countries; and, in order to be acquainted with its laws, he cauſed his mathematician, Simon Stephen, to write a book, this was publiſhed at Leyden in the year 1599. This excellent prince enjoined all ſeamen under his juriſdiction to make diligent obſervations in all their voyages, under conſideration of the great advantage which might accrue, if the variation of the needle in all places were truly known: he gave command to all that ſhould take charge of ſhips, that before they took their departure they ſhould provide themſelves proper inſtruments for this purpoſe, that, into what place ſoever they might come, they ſhould diligently obſerve the magnetic variation; and that, after their return into their own country, they ſhould give a true certificate of thoſe obſervations to the reſt of their colleagues, and companies of the admiralty, that by them they might be brought into order, and publiſhed for the general good; deſiring alſo to ſtir up other nations to the ſame care and diligence. In the ſame year 1599 this treatiſe was tranſlated into Engliſh by Edward Wright, Fellow of Caius College, Cambridge, that famous mathematician who invented or improved the projection of the ſphere, commonly called Mercator's. In his dedication to the Earl of Nottingham, ſeeming to forget his own additions, he tells him that he brings before his preſence that Dutch Pilot, (meaning the book) whom, ſince its arrival, he has taught to ſpeak Engliſh. This publication contains a table of variations, as obſerved at ſea and land (in contradiction to Pedro de Medina, who doubted the exiſtence of the variation) and aſſerted that the quantity was very different in different places; and that an allowance was neceſſary in ſteering the courſe of a ſhip. But all this time it ſeems nobody ſuſpected a variation of the variation; for Edward Wright (who was ſometime tutor to Prince Henry) tells us, "the ſame place hath always the ſame latitude and variation."

Dr. William Gilbert, phyſician in ordinary to Queen Elizabeth and to James I. in his book "de Magnete" publiſhed in 1600, gave his opinion on this abſtruſe matter: he ſuppoſed that the earth itſelf, being in all parts magnetical, and the water not, whereſoever the land was, thither alſo ſhould the needle turn, as to the greater quantity of magnetical matter. This opinion ſeems to have been long laid aſide, by common conſent; for ſome time after on the Coaſt of Brazil, the needle, inſtead of being attracted by the land, turned quite another way. Doctor Gilbert's book contains a number of curious experiments, but ſtill he was a ſtranger to the variation of the variation, for he aſſerts *Variatio uniuſcujus q; Loci conſtans eſt*: that is to ſay, the variation of every place is uniformly the ſame.

William Barlow, in the year 1613, in his book called "Magnetical Advertiſements" gives a number of experiments, but makes no attempt to form a theory. In the ſame year "A ſhort treatiſe of Magnetic Bodies and Motions" made its appearance, publiſhed by Doctor Mark Ridley, ſometime phyſician to the Emperor of Ruſſia. His opinions concerning the cauſe of the variation were nearly ſimilar to Doctor Gilbert's.

Francis Bacon, baron of Verulem, viſcount St. Albans, and lord high chancellor of Great Britain, is conſidered with propriety as the father of that valuable branch of philoſophy, founded on fact and obſervation: they that record his failings, like thoſe who have obſerved ſpots in the ſun, neither pretend to diminiſh his real brightneſs, nor deny the univerſal influence which he acquired in the world of ſcience. He began early in life to perceive that uſeful knowledge muſt be founded on the rock of experiment, and compoſed of more ſubſtantial materials than had been employed through a courſe of many centuries: in this his own genius, aided by a ſingular diſcernment, muſt have been his principal preceptor. A philoſophy built on this foundation could not make a ſudden general revolution in the learned world, but its progreſs, like that of time, quiet, ſlow, and ſure, has at length proved irreſiſtible and univerſal. Among his countrymen, the great names of thoſe who have adopted his notions, and proceeded on his plans, are his higheſt encomiums; to paſs over a long liſt of illuſtrious names, he reckons a Boyle, a Lock, and even a Newton, amongſt his followers.

If chancellor Bacon, who pointed out the path to thoſe ſublime heights in experimental philoſophy, at which his followers have arrived, did not himſelf diſcover the variation of the variation, yet as it was diſcovered by that mode of experiment which he recommended, he no doubt contributed thereto; for in the year 1622, being about four years before the chancellor's death, the variation was diſcovered to change in the ſame place by Profeſſor Edmund Gunter, of Greſham college, the inventor of that admirable ſcale or ruler which ſtill bears his name, who found it to be only 6° 13′ eaſt this year, which is 5° 2′ leſs than what it was recorded by Norman and Borough to have been forty-two years before. This diſcovery of the change of the variation has hitherto been attributed to Henry Gellibrand, profeſſor of aſtronomy and ſucceſſor to Gunter in Greſham College; but Profeſſor Gellibrand himſelf in "*A Diſcourſe Mathematical, on the Variation of the magnetic Needle,*" publiſhed in 1635, gives us the variation as obſerved both by Borough and Gunter; and as the latter found it to be 5° 2′ leſs than the former, it ſeems that Gunter firſt obſerved this alteration. No doubt Profeſſor Gellibrand firſt publiſhed to the world this variation of the variation, for he ſays an acquaintance of his, applying Gunter's own needle to the ſide of the cubical ſtone of the king's dial, in Whitehall Garden, he could not find it ſo great as was obſerved by Gunter: they went to Diepford (or Deptford) in 1633, the day of the ſun's entrance into the ſummer ſolſtice, and found it much leſs than 5° eaſt; and at the ſame place, on the 12th of June 1634, by the mean of nine azimuths, the refraction allowed for, the variation was 4° 1′ 53″ eaſt. The famous Fontinelle, perpetual ſecretary of the Academy of Sciences at Paris, in his Hiſtory of this Academy, has ſignified that Dr. Peter Gaſſendi, royal profeſſor of mathematics in that city, was the principal diſcoverer of this property. Gaſſendi was one of the moſt celebrated literary characters

France has produced, he wrote againſt the metaphyſical meditations of Rene Des Cartes, the author of the Carteſian ſyſtem of the univerſe, and divided with that great man the philoſophers of his time, almoſt all of whom were Carteſians or Gaſſendians; however, we read in the Cyclopædia, under the article Variation, that Gaſſendi himſelf acknowledged he had before received information of Gellibrand's obſervations.

Des Cartes alſo attempted a theory of the magnetic variation: he ſuppoſed the iron and loadſtone, hid in the bowels of the earth, and the bottom of the ſea, might be the cauſe of the variation of the needle. A plauſible hypotheſis is ſometimes more amuſing to the imagination than the patient and humble method of experimenting, and purſuing Nature through all her labyrinths by fact and obſervation.

Des Cartes has the merit of firſt applying algebra to geometry, but his Natural Philoſophy, which was publiſhed in the year 1659, has been entirely exploded even in his own country, ſince it came to be tried by the teſt of experiment. He long enjoyed ſo high a reputation that La Fontaine, who was the echo of the public voice, ſays, in ages paſt, when it was faſhionable to deify men, Des Cartes would have ranked as much above human beings as man is ſuperior to an oyſter.

On the 19th day of March 1674, Profeſſor Robert Hook, giving to the Royal Society of London, of which he was a member, ſome account of the magnetic variation, only mentioned one magnetic pole; and concludes by ſaying, "whe-

" ther it proceeds in a meridian, or in a parallel, or great " circle, or any other regular curve; and, if in a curve, " whether its concave or convex ſide be towards us, more " time and obſervation muſt make clear."

In proceſs of time it was found that the inclination (or dip) of the needle was more at one place than another. Henry Bond, after making this the ſubject of his ſtudy for many years, publiſhed a ſmall treatiſe on " *the Inclination of* " *the inclinatory Needle*." This was uſhered into the world by the expreſs command of King Charles II. to whom it was dedicated; and in this work he publiſhed tables of the Inclination, called Caroline tables, in honour of Charles, his royal patron. The zeal of this author, it ſeems, proved ineffectual; the learned Dr. Halley, F. R. S. and Aſtronomer Royal, ſays, that " Henry Bond pretends to calculate " the variation, but he limits his hypotheſis to the city of " London; affirming himſelf, as he had a great deal of rea" ſon, that the ſame calculus is not ſufficient for other " places; whereby it appears this rule is far ſhort of the ſo " much deſired general one." Bond's theory diſagreed widely with obſervation in another inſtance; for Dr. Halley remarks that, at the entrance of Hudſon's Bay and the mouth of the river of Plate, being nearly under the ſame meridian, at one place the variation in his time was 29½ degrees to the weſt, at the other 20½ degrees to the eaſt; he ſays this plainly demonſtrates the impoſſibility of reconciling theſe variations by the Theory of Bond; for, had it been a true one, under the ſame meridian the variation ſhould be in all parts of it the ſame way. The ſame Dr. Halley, who made ſo many real improvements in ſcience, ſpent much time in trying to aſcertain the laws of the magnetic variation: he publiſhed, in the year 1683, his firſt theory of the magnet, in which he made this concluſion. "The whole globe of the earth is one great magnet, having four "magnetical poles, or points of attraction; near each pole of "the equator two; and that, in thoſe parts of the world which "lie near adjacent to any one of theſe magnetical poles, the "needle is governed thereby, the neareſt pole being al"ways predominant over the more remote." Although Dr. Halley's firſt theory was favourably received at home and abroad, he was ſoon ſenſible of ſeveral inſurmountable difficulties in it. It is plain that the magnetic poles are not fixed, but moveable, as appears by the great changes of the needle's direction. In England, where this diſcovery was made, the direction of the needle has changed no leſs than 33 degrees in 200 years. Dr. Halley, probably conſidering the difficulty of forming any ſyſtem without a number of obſervations, made application to government in the reign of William and Mary, when this matter was conſidered in ſo favourable a point of view, that the command of the Paramour Pink, one of the ſhips of the royal navy, was given to Dr. Halley, with orders to ſeek by obſervation the diſcovery of the rule of the variation of the compaſs. He ſet ſail the firſt time, on the 20th of October 1698, for the ſouthern hemiſphere, and continued the voyage with great ſpirit until a diſpoſition for mutiny was diſcovered by the commander among his men; he then bore away for Barbadoes, in order to exchange them; but this being impoſſible, at that time and place, he returned to Great Britain, where he arrived in June 1699.

Having got his lieutenant tried and caſhiered, he ſet ſail, the ſecond time, in September following: he now traverſed the vaſt Atlantic ocean, in which he ſailed to the fiftieth degree of ſouthern latitude, and upwards. This voyage deſerves to be remembered longer than that made by the antient Grecian princes, the Argonauts, who, under the conduct of Jaſon, went to Colchis, to fetch the golden fleece from thence. Dr. Halley made magnetic obſervations at Brazil, St. Helena, Barbadoes, Bermudas, Newfoundland, and other places on land and ſea. He arrived in England in September 1700, and the next year publiſhed a chart on Mercator's projection; which will preſerve his name longer than braſs or marble. This was done by drawing lines through thoſe parts where the variation was equal; but his obſervations were by no means univerſal. Dr. Halley now ſatiſfied his firſt theory would not bear the teſt, communicated his ſecond to the Royal Society under the following appellation: "An Account of the Cauſe of the Change "of the Variation of the magnetical Needle, with an "Hypotheſis of the Structure of the internal Parts of the "Earth."

In this paper he ſays, "theſe difficulties had wholly made "me deſpond, and I had long ſince given over an enquiry "I had ſo little hopes of, when in accidental diſcourſe, and "leaſt expecting it, I ſtumbled on the following hypotheſis. "The external parts of the globe may well be reckoned as the ſhell, and the internal as a nucleus or inner "globe included within ours, with a fluid medium between, "which having the ſame common centre and axis of diurnal rotation, may turn about with our earth each "twenty-four hours; only this outer ſphere having its turbinating motion ſome ſmall matter either ſwifter or "ſlower than the internal ball: And a very minute differ-

“ ence in length of time, by many repetitions becoming “ ſenſible, the internal parts will by degrees recede from the “ external, and not keeping pace with one another will ap- “ pear gradually to move either eaſtwards or weſtwards by “ the difference of their motions.”

Dr. Halley ſuppoſes the fixed poles are the poles of this external ſhell or cortex of the earth, and the other two the poles of a magnetical nucleus, included and moveable within the other; and finally Dr. Halley concludes this motion is weſtward.

Inſtead of the motion of the magnetic influence moving weſtward, as Dr. Halley ſuppoſed, the two magnetic points will be found to move from weſt to eaſt; the northern one quicker, and the ſouthern ſlower, than the earth; ſo that the apparent revolution of the northern magnetic point is from weſt to eaſt, and the apparent revolution of the ſouthern magnetic point is from eaſt to weſt.

Since Dr. Halley’s chart was publiſhed, the greateſt part of a century has paſſed, affording many obſervations. I hope to prove clearly, in the following work, by calculations from the actual obſervation from which Dr. Halley’s chart was conſtructed, and from others, that two magnetic points alone, not diametrically oppoſite to each other, are ſufficient to account for the ſingular figure of the lines paſſing through the points of equal variation: if ſo, it will appear unphiloſophical to ſuppoſe more magnetic points than are abſolutely neceſſary to account for the phenomena.

The quantity of the variation being in a ſtate of fluctuation throughout the world: at the ſame place it changes, at one time quick, at another time ſlow; ſometimes almoſt ſtationary, and then retrograde; at the ſame time in different places, there is the ſame variety of changes. In the ſpace of forty years the lines, laid down by Dr. Halley, were grown entirely uſeleſs; for want of a knowledge of the principles of the variation, other charts could not be conſtructed without a multitude of obſervations. William Mountain and James Dodſon, Fellows of the Royal Society, undertook to renew the chart of Dr. Halley, and receiving the aſſiſtance of the commiſſioners of the navy, and of the directors of the Eaſt India, African and Hudſon's Bay companies, they obtained leave to peruſe the journals of thoſe mariners who were under the direction of each reſpective body; from which the charts were republiſhed for 1744 and 1756. From the great number of obſervations in their poſſeſſion, they doubted not at firſt of being able to draw lines repreſenting the variation at the four different periods, 1711, 1722, 1733, and 1744; and thence, by analogy, to have performed the ſame for 1755; but they ſoon found the impracticability of this ſcheme, as they themſelves acknowledge, experience having pointed out to them the irregular mutations of the variation. Any expectation before retained of reconſtructing a new ſet of lines, by analogy, ſoon vaniſhed; and they were obliged to purſue their tedious method of proceeding, by collecting the greateſt poſſible number of obſervations: thus they were enabled to approve of ſome and reject others; accordingly, as they were ſuppoſed to be ſupported or not by concurrent teſtimony, and from thence to draw lines repreſenting the variation at that time, they alſo publiſhed charts of the ſame kind for 1756; but thoſe charts of Mountain and Dodſon, not being conſtructed by their own obſervations, but from obſervations made by various captains of ſhips, the different methods of obſerving the variation, together with the uncertainty of the ſituations of places where the obſervations were made, theſe charts cannot be expected to be true in every part, any more than Dr. Halley's chart, which was not founded entirely on his own obſervations. Dr. Halley himſelf ſeems not to give them as exact, as well for want of a ſufficient number of obſervations, as principally becauſe many of the obſervations, upon which his chart was founded, were made long before the epocha of 1700.

It ſeems alſo as if Mountain and Dodſon would repreſent in their charts, at one particular time, both more ancient and more modern obſervations; moreover their charts give to the Eaſt India line, of no variation, ſuch an extravagant bend as no true theory can ever agree with; and ſuch an one as the former errors, to which the obſervations were ſubject, could never admit; notwithſtanding, it muſt be allowed theſe ſeveral charts, under all the diſadvantages the authors were then ſubject to, muſt have been highly uſeful in the art of navigation, eſpecially for ſteering the courſe of a ſhip.

In a ſhort eſſay, publiſhed by Edward Hawkſley, in 1745, he defines the magnetic poles to be two points diametrically oppoſite, towards which he ſays, the correſpondent points of the needle always tend. This doctrine was advanced by Henry Bond in the laſt century, but proved by Dr. Halley to be erroneous; for, if Bond's and Hawkſley's projects had been founded on juſt principles, under the ſame meridian, an, the variation ſhould be in all parts of it the ſame way; which is certainly very far from the truth, becauſe, it has been already mentioned, that, under the ſame meridian, the variation at one place was $29\frac{1}{2}°$ weſt, and at another place $20\frac{1}{2}°$ eaſt.

The diurnal variation, obſerved by Graham, Canton, and others, from actual experiments, ſeems reducible to certain fixed laws; therefore, this variation will hardly ever operate againſt the ſucceſs of the preſent plan.

Professor Leonard Euler's Memoir on the magnetic variation was publiſhed among the memoirs of the Royal Academy of Sciences and Belles Lettres, at Berlin, for the year 1757. Several of the Encyclopædiſts have attributed this to one of his ſons; ſome to his eldeſt ſon, John Albert Euler, knight of the order of St. Vladimir, and ſecretary to the imperial academy at Peterſburgh, his ſurname only being prefixed to the memoir, ſuch a miſtake might readily happen; but the princeſs of Daſchkaw, who now fills the father's place, as preſident of the imperial academy of Sciences at Peterſburgh, in one of the letters which ſhe has favoured me with, dated 31ſt of January 1792, ſays "the "author of that Memoir, *Recherches ſur la Déclinaiſon de* "*l'Aiguille aimantée*, in the *Memoirs de l'Academie royale des* "*Sciences de Berlin*, is the famous Leonard Euler, father to "him who is now ſecretary to our Academy." Profeſſor Euler's object is to ſhew, that there are but two magnetic poles, and theſe poles not diametrically oppoſite. The places of theſe magnetic poles he does not determine by calculation, but rather gueſſes at the ſituations they ought to occupy, to produce the Halleyan lines. Theſe elements he varies a number of times, as follows, to try which will beſt agree with the ſhape of the Halleyan lines: he ſuppoſes the diſtance between the arctic pole and the magnetic pole to be either 15°, 14° 55′, 14°, or 17°.

The diſtance between the antarctic pole and the magnetic pole to be either 25°, 29° 23′, 30°, 35°, or 40°.

The angle at the north pole, formed by the meridians paſſing through the two magnetic poles, he ſuppoſes to be either 40°, 45°, 53° 18′, or 63°.

In Profeſſor Euler's preface he remarks, that all thoſe who undertook this ſubject were ſoon obliged to abandon it, on account of the unconquerable difficulties which they met with; the principal cauſe was not ſo much in the ſtrange figure of Dr. Halley's lines, which are hardly capable of being explained by any rules in geometry, as in the perſuaſion which they had adopted, on the authority of Dr. Halley, that the phenomena of the magnetic variation were cauſed by four magnetic poles.

One of the reaſons why the Halleyan lines were ſo difficult to explain by the rules of geometry, is, becauſe Halley's chart is laid down on Mercator's (or Wright's) projection; now the degrees of longitude being known to grow ſhorter on the globe, in proceeding from the equator to either pole of the earth, this projection cauſes the degrees of latitude to increaſe on the chart, as the degrees of longitude diminiſh on a globe; by theſe means the continents are ſtrangely diſtorted; and although particular places preſerve nearly their proper bearings from each other, the relative magnitudes of iſlands, if ſituated in different latitudes, are entirely deſtroyed. In the preſent projection the magnetic meridians are drawn on a new plan, and very different from Dr. Halley's: they are ſo conſtructed that they form curves truly geometrical, and come within the moſt rigid rules of calculation.

PROFESSOR EULER fixes neither the latitudes, the longitudes, the revolutions, nor courſes of the magnetic poles; neither does it appear that he propoſed to diſcover the longitude by the magnetic variation. Moreover, what Profeſſor Euler calls magnetic poles, I have taken the liberty to call magnetic points; giving the name of magnetic poles to the poles of the magnetic equator.

IN Profeſſor Euler's remarks, at the latter end of his Memoir, he mentions the uncertainty in which he ſtill remained reſpecting the true poſition of the magnetic poles. I think I may ſafely affirm, that, if the places of the magnetic points had been truly calculated, there would have been ſuch an agreement between the obſervations and calculations, as appears in the ſequel.

THE laſt paragraph of Profeſſor Euler's Memoir is entitled, *Hypotheſe:* his conjecture is, that the magnetic poles moved from eaſt to weſt. Contrary to this opinion, I hope to prove by calculation, that both magnetic points move round the poles of the earth, from weſt to eaſt; the northern one quicker, and the ſouthern ſlower than the earth; therefore, the apparent revolution of the northern magnetic point is from weſt to eaſt, but the apparent revolution of the ſouthern magnetic point is from eaſt to weſt. However, it is univerſally admitted, that Profeſſor Euler extended his reſearches on this ſubject far beyond all his predeceſſors; but, as many of the principles were left unexplored by him, he could not apply them to the diſcovery of the longitude. No wonder, for his biographers lament that his Memoir on the Loadſtone, that of the Propagation of Sound, the Laws of Coheſion, and thoſe of Friction, although ſubjects of learned calculations, were ſupported, unfortunately, by hypotheſis, rather than by experiment. In addition to what Profeſſor Euler wrote on the ſubject, it ſeems abſolutely neceſſary that all the following elements ſhould be well underſtood:

1. The nature of the curves formed by the magnetic meridians.

2. The periods of revolution of the two magnetic points.

3. The true courſes which they run.

4. Their latitudes.

5. Their longitude from ſome meridian for the preſent time.

6. A set of tables of their ſituation for any paſt or future period.

7. A set of rules, for applying all thoſe principles and materials to uſe.

Without an accurate knowledge of all theſe elements, Profeſſor Euler could not be ſuppoſed to apply the magnet to the diſcovery of the longitude; nevertheleſs, this great man ſeems to have had a diſtant proſpect, that this would one day be the caſe; for the Princeſs of Anhalt-Deſſau, having an uncommon taſte for knowledge in natural philoſophy, applied to Profeſſor Euler, and received leſſons from him, which were originally written in German, and afterwards publiſhed in French, at Berlin, in the year 1775, under the title of "Lettres à une Princeſſe D'Allemagne, ſur "divers Sujets de Phyſique et de Philoſophie." In theſe letters, he ſays indeed, it is not improbable that by theſe means we may in time, when the knowledge of them ſhall be more cultivated, be able to determine the longitude in a manner beſt applicable at ſea: though as yet we have, ſays he, made but ſmall advances towards it.

After informing the Princeſs that the variation at Berlin, in the year 1761, was then 15° weſt, he ſays, it now appears as if it would decreaſe, until it comes to nothing again. This certainly diſagrees with obſervation; for, in the report which the Commiſſioners made, by appointment of the Royal Pruſſian Academy, on my communications, I am informed by one of them, that the variation at Berlin, in the year 1791, inſtead of being leſs than 15° weſt, as Profeſſor Euler ſuppoſed, it was actually 17° 32′ weſt; and it will be found, that the variation will ſtill be much greater weſtward than it is at preſent at Berlin, before it begins to decreaſe.

Professor Euler obligingly informs the Princeſs, his pupil, that an accurate knowledge of the preſent variation generally, whether eaſt or weſt, would be a moſt valuable acquiſition; but he ſeems to deſpair of this knowledge ever being obtained; and proceeds to remark, that our knowledge in this part of natural philoſophy had not then arrived to any degree of perfection.

PROFESSOR EULER gives the Princeſs his opinion, that iron mines, within the bowels of the earth, cauſe this peculiar direction of the needle; but as it will appear, by calculation, that the revolutions of the two magnetic points are uniform, I cannot perceive the poſſibility of iron mines performing regular revolutions through ſea and land, as they move round the poles of the earth.

To Profeſſor Euler, in particular, I hold myſelf under many obligations. If he did not arrive at perfection in the doctrine of the magnet, he caſt much light on the ſubject; indeed there is ſcarcely a ſingle branch of mathematical ſcience that has not been improved by his labours. No geometrician ever before embraced ſo many objects at the ſame time: none has perhaps ever equalled him in the number of his publications, or in the multitude and variety of his diſcoveries.

THE labours of Euler will appear more aſtoniſhing when it is conſidered, that, while he was enriching the Royal Academy of Berlin with a prodigious number of memoirs, on the deepeſt parts of mathematical ſcience, which were generally preſented in new points of view, interſperſed with ſublime truths, and ſometimes with diſcoveries of great importance; he did not diſcontinue his philoſophical contributions to the imperial Academy of Peterſburgh. There is ſcarce one of his pieces which does not contain ſome ingenious view, that may lead to the ſucceſsful inveſtigation of truths yet unknown. The civil and literary hiſtory of all ages and all nations was familiar to him; and foreigners, who were acquainted with his works, were aſtoniſhed to find in the converſation of a man, whoſe long life ſeemed ſolely occupied in mathematical and phyſical reſearches and diſcoveries, ſuch an extenſive acquaintance with other intereſting branches of literature; his memoirs diſplay the marvellous fecundity of his genius; he carried to new degrees of perfection the integral calculus, reduced analytical operations to a greater degree of ſimplicity, and was thus enabled to throw new light on all the parts of mathematical ſcience: his Elements of Algebra, by their intrinſic merit, in point of perſpicuity and method, have equally excited applauſe and aſtoniſhment.

It is well known that Profeſſor Euler reduced Sir Iſaac Newton's Theory of the Moon into elegant analytical expreſſions, of which Tobias Mayer availing himſelf, he was, by a very ſingular addreſs of his own, enabled to bring out the greateſt quantities of the equations, with eaſe and exactneſs; and thence to conſtruct tables agreeing to the Moon's motion in every part of her orbit. The board of longitude having rewarded Euler and Mayer for their ſervices, the tables were publiſhed in 1770 by Dr. Maſkelyne, Aſtronomer Royal, who has the merit of firſt planning the Nautical Almanack.

Euler was perſonally known to moſt of the Princes in the northern parts of Europe, who ſhewed him marks of their eſteem or rather veneration, which they could not well refuſe to a man, who united the ſimplicity of virtue to a genius ſo vaſt and ſublime; but he never could be prevailed upon to receive any title offered to him, except that of Profeſſor: to a man like him, the pleaſure of ſtudy muſt be a reward much more agreeable than glory.

The author of Profeſſor Euler's *Eloge* ſays, that the whole of his labours conſiſt of more than thirty different works, publiſhed ſeparately; and nearly ſeven hundred memoirs, two hundred of which were depoſited at the imperial Academy of Sciences at Peterſburgh, after his death, and intended to enrich their future collections.

If praiſe, as Plato ſays, is the ſweeteſt kind of muſic, as Euler lived to a great age, he long enjoyed a concert of that kind. His death was conſidered as a public loſs: the Academy of Peterſburgh appeared formally in mourning, and voted a marble buſt to his memory, which was placed in the Hall at the expence of the Princeſs de Daſchkaw, who fills his place, as preſident of the imperial Academy, to whom I hold myſelf under many obligations, for ſeveral valuable communications.

In the year 1766 was publiſhed, at Worceſter, "A brief "Theory of the north magnetic Pole." The author, as he only attempted a theory of one magnetic pole, ſeems to fall far ſhort of perfection; for if the needle was influenced only by a northern magnetic pole, the ſouth end would have a direction to another point diametrically oppoſite: in that caſe the line of no variation would coincide with a meridian of the earth: but this would in no wiſe agree with obſervation, and would in every reſpect be ſubject to the ſame objections as Dr. Halley made againſt Bond's theory, in the begining of the preſent century; for, if this theory had been a true one, under the ſame meridian the variation would be in all parts of it the ſame way; this is well known not to be the caſe. The elegant "Eſſay on "Electricity," by George Adams, mathematical inſtrument maker to his Majeſty, is well known, being publiſhed in the year 1787. At the latter end of this we are given to underſtand, that the "powers of genius, which have been hither-"to employed in proſecuting this ſubject, have not been "able to frame an hypotheſis that will accouut, in an eaſy "and ſatisfactory manner, for all the various properties of "the magnet, or point out the links of the chain which con-"nect it with the other phenomena of the univerſe."

It does not appear that Samuel Dunn ever favoured the world with a publication of the principles of his formerly ſuppoſed theory of the magnetic variation; his *New Atlas of the Mundane Syſtem, or of Geography and Coſmography, deſcribing the Heavens and Earth, &c.* was publiſhed in 1788: in this ſplendid work he ſays, in page 16, "This "variation of the compaſs is occaſioned by the action of "certain powers in the magnetic ſyſtem, whoſe laws are "not yet fully diſcovered; and therefore but few conclu-"ſions can be drawn concerning the doctrine of magnetic "variations, and thoſe muſt be deduced from obſervations "and experiments."

In a diſſertation on "the Elements of Navigation," publiſhed 1780, by John Robertſon, late librarian to the Royal Society, we are informed, "the laws of the variation ſeem "to have hitherto eluded all our reſearches."

In Gibſon's Philoſophy we are told what the variation was at a certain place, when the work was publiſhed in 1785; but, ſays the author, "how long it will continue ſo, "time and obſervation muſt only determine."

A Treatiſe on Magnetiſm, in Theory and Practice, with original Experiments, by Tiberius Cavallo, F. R. S. is very well ſpoken of: it treats more on experimental magnetiſm than the magnetic variation, and contains many curious experiments well worthy of peruſal. In page 112 the author remarks, that "no Theory yet offered has been ſufficient to "foretel, with certainty, the variation of the needle for any "future period of time, or for any place diſtant from thoſe "in which obſervations have been frequently made." In page 324, in ſpeaking of the different hypotheſes, he ſays, neither have their predictions anſwered, nor were any of them founded upon evident principles. In this celebrated work are inſerted four caſes, drawn up by Dr. Lorimer, whoſe extenſive knowledge is well known; in the laſt caſe he repreſents it almoſt impoſſible to form a true theory, and ſays, "however, as this is a ſubject of vaſt importance to man- "kind, principally for the improvement of navigation, I am "far from meaning to diſcourage its being properly examin- "ed; but only think it neceſſary to put all the apparent "difficulties before the eye of the reſolute adventurer in "this field of intricate and difficult inveſtigation."

NOTWITHSTANDING Nicholſon's Philoſophy teaches us that the effects of magnetiſm are obſerved with ſurpriſe and admiration, while the moſt cautious confeſs that the cauſe is entirely unknown, the ſame author in Vol. II. page 329, ſays, he knows from experience, that the magnetic variation may be eaſily obſerved, in moderate weather, to the certainty of a leſs error than ten minutes: if ſo, there will be but little difficulty in finding the longitude by the magnetic variation. The variation of the Compaſs is certainly of that great concern in Navigation, that the want of a true theory has heretofore done little leſs than rendered uſeleſs one of the moſt noble inventions mankind ever attained to. This is a ſentiment that has often been expreſſed by different writers.

The fifth volume "*Hiſtoire Naturelle des Minéraux*" of Comte de Buffon, was publiſhed at Paris in 1788: This work contains a multitude of magnetic obſervations made by many circumnavigators; but the author ſays, it does not ſeem probable that we ſhould, by any former obſervations, however numerous and repeated, be enabled to fix on any preciſe ſyſtem for the progreſſive and retrograde motion of the needle; nevertheleſs, when the principles are properly underſtood, their ſimplicity will appear evident by the following calculations and demonſtrations, founded on actual obſervations.

The Hydrographer to the Duke of Clarence, in page 165 of his book, entitled, "The Practical Navigator and "Seaman's New Daily Aſſiſtant," publiſhed 1791, in treating of the Variation of the Compaſs, ſays, "the true "cauſe and theory of which has not yet been diſcovered." An idea of the value of this work may be formed by its extenſive circulation.

Several of the Encyclopædiſts, in their late ſplendid editions ſay, "whether the magnetic poles move alto- "gether with one motion, or with ſeveral, whether equal-

" ly or unequally, whether circular or libratory; if circu-
" lar, about what centre; if libratory, after what man-
" ner, is unknown."

After having ſeen the preceding difficulties painted in ſuch high colours, it may appear bold in me to purſue this ſubject; yet the encouragement I have received has led me on ſtep by ſtep, and I hold myſelf particularly indebted for the magnetical obſervations publiſhed in the Voyages of Captain Cook. The learned Dr. Andrew Kippis, in his account of the life of that renowned navigator, writes as if he had a clear proſpect of the advantages that would ariſe from his obſervations, " in determining the cauſe and nature of the polarity of the needle."

The " Meteorological Obſervations and Eſſays, by John " Dalton, Profeſſor of Mathematics and Natural Philoſophy, at the new College of Mancheſter," makes mention of the relation between the Aurora borealis (northern lights) and what he calls the earth's magnetiſm.

The advertiſements, concerning this work, juſt before it made its appearance in 1793, announced his diſcovery of this relation to be original, the author not knowing that any other writer had publiſhed the moſt diſtant intimation thereof; but, before his book was printed, Profeſſor Dalton acknowledges, with candour, that he had ſeen a paper, by an anonymous author, printed in a periodical publication for May 1792, entitled, " *Mathematical, Geometrical, and Philoſophi-" cal Delights;*" in which the ſaid anonymous author mentions ſomething to the ſame purpoſe.

I MUST here beg leave to refer the reader to my own three letters deſcribing fully this relation. They were addreſſed to Count de Caſſini, director of the royal obſervatory at Paris, and publiſhed in the city of Philadelphia, in October 1788, in a periodical publication, entitled, the "American Muſeum" this was ſeveral years prior to the paper of the ſaid anonymous author. In the firſt of theſe letters, the rays of the northern lights are clearly deſcribed to agree with the magnetic meridian; for when the northern magnetic point was laſt on the ſame ſide of the earth as England, the northern lights were very frequent in that kingdom for many years, until they gradually diſappeared; ſince when, and while the northern magnetic point was in the oppoſite ſide of the Earth from England, they were inviſible in England for a conſiderable time. Some of the laſt that are upon record, as having appeared there before thoſe of the preſent century, are thoſe of January 30th 1560, October 7th 1564, and November 14th and 15th 1574. According to Rowning's Philoſophy, vol. I. page 243; after a long abſence, a ſmall one appeared in Ireland, November 16th 1707; another appeared in England, Auguſt 9th 1708; a remarkable one appeared there alſo March 16th 1715-16; they have been, and ſtill continue to be, very common in Great Britain ever ſince; and the nigher the magnetic point comes to the meridian of any place, the more frequent theſe appearances are.

DR. John Reinold Foſter, F. R. S. in an account of his voyage round the world, remarks that, although he and others, in company with Captain Cook, had ſpent ſeveral different ſeaſons near the Antarctic Circle, yet they never ſaw the ſouthern lights (Aurora Auſtralis;) but in the year

1773, being then between the latitude of 58° and 60° ſouth, their appearance, on ſeven different nights, was much the ſame as thoſe of the northern lights.

They ſaw the Southern lights on February 18th, 19th, 20th, 21ſt, and 26th; alſo on March 15th and 16th.

It is remarkable, although Dr. Foſter did not mention it, that the obſervers of thoſe ſouthern lights were not more than about 13 degrees of a great circle from the place of the ſouthern magnetic point.

Because Dr. Foſter obſerved theſe ſouthern lights at the aforeſaid places, ſeveral writers have concluded that they were viſible in every part of the ſouthern hemiſphere. I conſider that concluſion to be contrary to obſervation; as the ſouthern lights are not mentioned by Dr. Foſter to be viſible, except on the ſame ſide of the earth which the ſouthern magnetic point is now found to occupy.

THE

MAGNETIC ATLAS, &c.

CHAP. I.

DEFINITIONS AND COROLLARIES.

DEFINITION I.

THE two points D and E, which give an univerſal direction to the magnetic needle, and repreſented in the ſphere drawn round the centre C, fig. 1. may be termed magnetic points.

DEF. II. That magnetic point D, which is ſituate in the northern hemiſphere, at a certain diſtance from the north pole of the earth, may be called the northern magnetic point.

DEF. III. That magnetic point E, which is ſituate in the ſouthern hemiſphere, at a certain diſtance from the ſouth pole of the earth, may be called the ſouthern magnetic point.

DEF. IV. The half of a great circle, drawn from one pole of the earth to the other, through any given place, is the terreſtrial meridian of that place.

DEF. V. All the curves which meet in the magnetic point, on either of the charts, are the magnetic meridians.

DEF. VI. The angle contained between the magnetic meridian, and the meridian of the earth, in any place, is the variation of the compaſs for that place.

Def. VII. The time in which either magnetic point revolves round the pole of the earth, from a conjunction with any fixed ſtar, until its return to the ſame again, may be termed its ſidereal, or real, revolution.

Def. VIII. The time which either magnetic point requires, from its leaving any one meridian of the earth, until its return to the ſame again, may be termed its periodical, or apparent, revolution.

Def. IX. A line drawn through the different parts of the globe, where the magnetic needle points due north, is the line of no variation.

Corollary. I. The line of no variation changes its place as the two magnetic points change their places.

Cor. II. The line of no variation alters its curvature in proportion to the different poſitions of the two magnetic points.

Cor. III. Whenever the two magnetic points are neither on the ſame, nor on oppoſite, meridians of the earth, then thoſe parts, where a meridian of the earth makes a tangent to a magnetic meridian, there the line of no variation paſſes.

Def. X. A point G, diametrically oppoſite to the ſouthern magnetic point E, may be termed the northern magnetic nadir.

Def. XI. A point H, diametrically oppoſite the northern magnetic point D, may be termed the ſouthern magnetic nadir.

Cor. I. If the two magnetic points were at equal diſtances from the two poles of the earth, and on oppoſite meridians, they would be diametrically oppoſite to each other.

Cor. II. If the two magnetic points were diametrically oppoſite to each other, the magnetic meridians would all be arches of great circles.

Cor. III. As the two magnetic points are neither at equal diſtances from the two poles of the earth, nor at preſent on oppoſite meridians, they are not diametrically oppoſite to each other. Hence none of the magnetic meridians, except the firſt and the laſt, are arches of great circles.

Cor. IV. The diſtance between the magnetic points and the magnetic equator is different on different ſides of the globe.

Def. XII. A great circle ICK, drawn every way equally diſtant from and between the two magnetic points and the two magnetic nadirs, will be the magnetic equator.

Def. XIII. Thoſe two oppoſite points LM, ſituate ninety degrees from the magnetic equator ICK, are the poles of the magnetic equator.

Cor. I. The magnetic equator, as well as the firſt and laſt magnetic meridian, continually changes its place.

Cor. II. The magnetic equator divides the globe into two equal parts.

Cor. III. Every circle, dividing the globe into two equal parts, is a great circle.

Cor. IV. Every great circle has two poles.

Cor. V. The two poles of every great circle are diametrically oppoſite to each other.

Cor. VI. Hence the two magnetic poles, being diſtinct from the two magnetic points which influence the direction of the needle, are nothing more than the poles of the magnetic equator.

Def. XIV. A right line DNE, drawn from one magnetic point to the other, may be called the magnetic pointer axis.

Def. XV. A right line LCM, drawn from one magnetic pole to the other, may be termed the magnetic polar axis.

Def. XVI. A right line GOH, drawn from one magnetic nadir to the other, may be called the magnetic nadir axis.

Cor. I. The magnetic polar axis, and no other, paſſes through the centre C of the earth.

Cor. II. The magnetic polar axis is equally diſtant from and between the magnetic pointer axis and magnetic nadir axis, all of which are parallel to each other; but,

Cor. III. As the two magnetic points are not diametrically oppoſite to each other, the diſtance between the magnetic points and the magnetic equator is different on different ſides of the globe.

Cor. IV. As the two magnetic points move with unequal velocities, the diſtance between the magnetic pole and the magnetic point undergoes a continual alteration.

Def. XVII. As the magnetic equator divides the globe into two equal parts, for diſtinction, one half may be called the northern, and the other the ſouthern magnetic hemiſphere.

Cor. I. In each magnetic hemiſphere the magnetic pole is, at any given time, equally diſtant from the magnetic point and the magnetic nadir.

Def. XVIII. A magnetic needle, ſuſpended on a pin paſſing through its centre in a horizontal direction, is a dipping needle.

Cor. I. Magnetic powers of equal force having equal influence at equal diſtance, as the magnetic equator is equally diſtant from each magnetic point, if the dipping needle ſtood horizontal on the magnetic equator, this would prove the influence of each magnetic point to be equal.

Cor. II. If the influence of each magnetic point were equal, the magnetic meridians would all be circular curves.

Cor. III. If the magnetic meridians were all circular curves, they might be conſidered as arches of regular polygons of an infinite number of ſides, and the horizontal needle would always repreſent one of theſe ſides.

Cor. IV. Although none of the magnetic meridians, except the firſt and laſt, are circular curves, the horizontal needle makes always a tangent to the magnetic meridian.

Cor. V. In the northern magnetic hemiſphere the dipping needle gives north dip, and ſouthern ſouth dip, proportionally to the diſtance from the place where it ſtands horizontal.

Def. XIX. The diſtance between the northern magnetic point and the north pole of the earth, may be called the north polar diſtance.

Def. XX. The diſtance between the ſouthern magnetic point and the ſouth pole of the earth may be called the ſouthern polar diſtance.

Def. XXI. An arch of a great circle DKE, paſſing from one magnetic point to the other, through each magnetic nadir, and from which all the other magnetic meridians are numbered, may be called the firſt magnetic meridian.

Def. XXII. The oppoſite arch, DIE, of the ſame great circle, 180° from the firſt, may be called the laſt magnetic meridian.

Def. XXIII. Lines drawn through thoſe parts of the earth, where the magnetic variation is equal, after the manner of Dr. Halley, are called Halleyan lines.

Def. XXIV. The mean time taken by the ſun, from its leaving one meridian of the earth, until its return to the ſame again, being 24 hours, as the mean time of the rotation of the earth on its axis from weſt to eaſt is determined and known to be 23h. 56′ 4″, this laſt mentioned time is called a ſidereal day.

CHAP. II.

SOLUTION OF PROBLEMS.

PROBLEM I.

HAVING the latitude of the place of obſervation, the variation of the compaſs, and the longitude of the northern magnetic point given, to determine the north polar diſtance.

Example. In the beginning of the year 1794, the firſt magnetic meridian paſſing near the Royal Obſervatory at Greenwich, which is in latitude 51° 28′ 40″ north, the variation of the compaſs was there 23° 56′ weſt, the longitude of the northern magnetic point being 135° weſt.

As radius 90° - - - -	10.0000000
Is to ſine of the latitude 51° 28′ 40″ - -	9.8934120
So is tangent of variation 23° 56′ - -	9.6472217
	19.5406337
To co-tangent of a 4th number 70° 51′ 3″ -	9.5406337

As co-ſine 135°—70° 51′ 3″=64° 8′ 57″	9.6395161
Is to co-ſine 70° 51′ 3″	9.5159118
So is co-tangent latitude 51° 28′ 40″	9.9009509
	19.4168627
To tangent north polar diſtance 30° 55′	9.7773466

PROBLEM II.

Having the latitude of the place of obſervation, the north polar diſtance, and the longitude of the northern magnetic point given, to determine, by calculation, the variation of the compaſs.

Example. The Royal Obſervatory, at Greenwich, being in latitude 51° 28′ 40″, in the ſpherical triangle, ACD, plate I. the north polar diſtance, AC, by propoſition the 1ſt, being 30° 55′, the compliment of the latitude, AD, being 38° 31′ 20″, and the longitude of the northern magnetic point being 135° weſt.

North polar diſtance 30° 55′ =30° 55′
Compliment latitude 38° 31′ 20″ =38° 31′ 20″

Sum 69° 26′ 20″ dif. 7° 36′ 20″ angle CAD 135°

$\frac{1}{2}$ Sum 34° 43′ 10″ $\frac{1}{2}$dif. 3° 48′ 10″ $\frac{1}{2}$angle CAD 67° 30′

As ſine $\frac{1}{2}$ ſum of the two ſides 34° 43′ 10″	9.75551
Is to ſine $\frac{1}{2}$ their difference 3° 48′ 10″	8.82134
So is co-tangent $\frac{1}{2}$ angle CAD 67° 30′	9.61722
	18.43856
To tangent $\frac{1}{2}$ ſine other two angles 2° 46′	8.68305

As co-ſine $\frac{1}{2}$ ſum of 2 ſides 34° 43′ 10″ - - 9.91486
Is to co-ſine $\frac{1}{2}$ difference 3° 48′ 10″ - - 9.99904
So is co-tangent $\frac{1}{2}$ angle CAD 67° 30″ - - 9.51722

19.61626

To tangent $\frac{1}{2}$ ſum other 2 angles 26° 42′ - - 9.70140
2° 46′

23° 56′ variation.

PROBLEM III.

Having the latitude of the place, the longitude of the northern magnetic point, and the variation of the compaſs given, to determine the diſtance to the northern magnetic point from the place of obſervation.

Rule 1ſt. Add the north polar diſtance, the compliment of the ſine of half the ſum of the angels given, the ſine of half their difference, and the tangent of half the given ſide together, the ſum, abating radius, is the tangent of half the difference of the ſides required.

2d. Add the compliment of the co-ſine of half the ſum of the given angles, the co-ſine of half their difference, and the tangent of half the given ſide together; the ſum, abating radius, is the tangent of half the ſum of the ſides required.

3d. Add the half difference of the ſide required to their half ſum, this will give the greateſt ſide, and ſubtract the half difference from the half ſum, this will give the leſſer ſide required.

Example. The Royal Obſervatory at Greenwich being in latitude 51° 28′ 40″, the longitude of the northern magnetic point being about 135° weſt, in the beginning of the year 1794, and the variation of the compaſs being 23° 56′ weſt.

Angle CAD	135° 0′=		135° 0′		
Magnetic variation	23° 56′=		23° 56′		
Sum	158° 56′	dif.	111° 4′	comp. lat.	38° 31′ 20″
½ Sum	79° 28′	½ dif.	55° 32′	½ co. lat.	19° 15′ 40″

Com. of S. ½ ſum 79° 28′	0.00738	Com. of co-S. ½ ſum	0.73801
Sine ½ difference 55° 32′	9.91617	Co-ſine ½ diff.	9.75276
Tan. ½ com. lat. 19° 15′ 40″	9.54309	Tang. ½ com. lat.	9.54309
Tangent 16° 19′	9.46664	Tangent 47° 14′	10.03386

47° 14′+16° 19′=63° 33′ the diſtance to northern magnetic point.
47° 14′—16° 19′=30° 55′ the north polar diſtance as before.

PROBLEM IV.

Having the latitude of the place of obſervation, the north polar diſtance, and the diſtance to the northern magnetic point given, to determine the longitude of the northern magnetic point, in the beginning of the year 1794.

Example.

North polar diſtance	30° 55′ 0′	Sine	9.71079
Compliment of latitude Greenwich	38° 31′ 20″	Sine	9.79431
Diſtance to northern mag. point	63° 33′ 0′	Rectangle	19.50510
Sum	132° 59′ 20″		
½ Sum	66° 29′ 40″	Sine	9.96240
Diſtance to northern mag. point	63° 33′ 0′		
Difference	2° 56′ 40″	Sine	8.70905
		Rectangle	18.67145

As rectangle ſine, CA+AD, plate I. - - -		19.50510
Is to ſquare of radius - - - - -		20.00000
So is rectangle ſine ½ ſum 3 ſides and difference ſide CD		18.67145
		38.67145
		19.16635
To ſquare of co-ſine ½ contained angle	67° 30′	9.58317
	2	
Longitude of northern magnetic point	135° 00′	

* * *

PROBLEM V.

Having the ſituation of the place of obſervation, the longitude of the ſouthern magnetic point, and the variation of the compaſs for a certain time given, to determine the ſouth polar diſtance, and alſo the diſtance to the ſouthern magnetic point from the place of obſervation.

Example. The firſt magnetic meridian paſſing near to 40° ſouth latitude, and 30° eaſt longitude from Greenwich, the ſouthern magnetic point being 128° 50′ eaſt from the place of obſervation in the latter end of the year 1793, and the variation of the compaſs being 21° weſt.

Longitude of ſouthern magnetic point	128° 50′ =	128° 50′
Magnetic variation	21° 0′ =	21° 0′
Sum	149° 50′	dif. 107° 50′
½ Sum	74° 55′	½ dif. 53° 55′

Compliment of latitude	50°
½ Compliment of latitude	25°

Comp.

Com. of S. of ½ ſum 74° 55′	0.01523	Comp. of co-S. 74° 55′	0.58465
Sine of ½ diff. 53° 55′	9.90750	Co-ſine 53° 55′	9.77009
Tang. ½ comp. lat. 25°	9.66867	Tangent 25°	9.66867
Tangent 21° 19′	9.59140	Tangent 46° 33′	10.02341

46° 33′—21° 19′=25° 14′ ſouth polar diſtance
46° 33′+21° 19′=67° 52′ diſtance to ſouthern magnetic point

PROBLEM VI.

Having the latitude of the place, the ſouth polar diſtance, and the diſtance to the ſouthern magnetic point given, to find the longitude of the ſouthern magnetic point.

Example.

Complement of the latitude	50°	Sine	9.88425
South polar diſtance	25° 14′	Sine	9.62972
		Sum	19.51397
Diſtance to ſouth mag. point	67° 52′		
Sum	143° 6′		
½ Sum	71° 33	Sine	9.97708
Diſtance to ſouth. mag. point	67° 52′		
Difference	3° 41′	Sine	8.80782
		Sum	18.78490

As rectangle ſine 50°+25° 14′ - - - 19.51397
Is to ſquare of radius - - - - 20.00000
So is rectangle ſine of ½ ſum of 3 ſides and dif. ſide CD 18.78490

38.78490
To ſquare of co-ſine of ½ contained angle 64° 25′ 19.27093
2

E. longitude of ſouthern magnetic point 128° 50′ from place obſervation.
Place obſervation E. Greenwich 30° 0′

Southern mag. point E. Greenwich 158° 50′

◆

PROBLEM VII.

Having the latitude of the place of obſervation, the ſouth polar diſtance, and the longitude of the ſouthern magnetic point given, to determine by calculation the variation of the compaſs in the ſouthern hemiſphere for the preſent time.

Example. The firſt magnetic meridian paſſing near 40° ſouth latitude, and 30° eaſt longitude from Greenwich, the ſouth polar diſtance being 25° 14′, and the longitude of the ſouthern magnetic point being 128° 50′ eaſt from the place of obſervation, in the latter end of the year 1793.

South Polar diſtance 25° 14′ = 25° 14′
Compliment of latitude 50° 0′ = 50° 0′

Sum 75° 14′ dif. 24° 46′ lon. mag. point 128° 50′

½ Sum 37° 37′ ½ dif. 12° 23′ ½ lon. mag. point 64° 25′

As ſine of $\frac{1}{2}$ Sum of the 2 ſides	37° 37′	9.78560
Is to ſine of $\frac{1}{2}$ difference	12° 23′	9.33133
So is co-tangent of $\frac{1}{2}$ angle	64° 25′	9.68012
		19.01145
To tangent	9° 33′	9.22585

As co-ſine $\frac{1}{2}$ ſum of the 2 ſides	37° 37′	9.89879
Is to co-ſine of $\frac{1}{2}$ their diff.	12° 23′	9.98978
So is co-tangent $\frac{1}{2}$ angle	64° 25′	9.68012
		19.65990
To tangent	30° 33′	9.77111
	9° 33′	
Variation	21° 0′	

PROBLEM VIII.

HAVING the ſituation of the place of obſervation, the variation of the compaſs, and the ſouth polar diſtance given, to determine the longitude of the ſouthern magnetic point for a time that is paſt.

Example. In latitude 30° ſouth, longitude 3° eaſt, the variation of the compaſs in the year 1700, according to Dr. Halley's Chart, was 4° weſt, the ſouth polar diſtance, by Problem V. being 25° 14′. In the ſame year the firſt magnetic meridian extended near to that place.

Sine of latitude 30°	9.69897
Tangent of variation 4°	8.84464
Co-tangent ſum (abating radius) 88°	8.54361

Co-ſine

Co-ſine 88°		8.54282
Co-tangent latitude 30°		10.23856
	Sum	18.78138
Tangent ſouth polar diſtance 25° 14′		9.67327
Co-ſine 82° 37′		9.10811

88°+82° 37′+3°=173° 37′ the longitude of ſouthern magnetic point.

PROBLEM IX.

HAVING the longitude of the northern magnetic point given for two different periods of time, to determine the apparent or periodical revolution of the northern magnetic point round the north pole of the earth.

Example. THE northern magnetic point being 180° weſt, in the year 1657, and by Problem IV. 135° weſt in the beginning of the year 1794; 1794—1657=137 years, and 180°—135°=45°. As 45° is to 137 years, ſo is 360° to 1096 years, the periodical revolution required.

PROBLEM X.

HAVING the longitude of the ſouthern magnetic point given for two different times, to determine its periodical revolution.

Example. THE ſouthern magnetic point, by Problem VIII. being 173° 37′ eaſt, in the year 1700; and by Problem VI. 158° 50′ eaſt in the beginning of the year 1794; we have 1794—1700=94 years, and 173° 37′—158° 50′=14° 47′. As 14° 47′ is to 94 years, ſo is 360° to $2289\frac{57}{887}$ years, the periodical revolution required.

PROBLEM XI.

HAVING the periodical revolution of the ſouthern magnetic point given to determine its ſidereal revolution.

Example. THE periodical revolution of the ſouthern magnetic point, omitting the fraction, being 2289 years; ſay, as 2289 years is to 360°, ſo is 1 day to 1″ 33‴. Again, ſeeing 15° longitude is equal to 60 minutes of time; as 15° is to 60′, ſo is 1″ 33‴ to 6‴ of time. The length of a ſidereal day being 23h 56′ 4″. If the ſouthern magnetic point moved faſter than the earth, this time ſhould be ſubtracted from the ſidereal day; but, as it moves ſlower, it is added thus, 23h 56′ 4″ + 6‴=23h 56′ 4″ 6‴, the ſidereal revolution of the ſouthern magnetic point.

PROBLEM XII.

HAVING the periodical revolution of the northern magnetic point given, to determine its ſidereal revolution.

Example. THE periodical revolution of the northern magnetic point being 1096 years; as 1096 years is to 360°, ſo is 1 day to 3″ 14‴; then, to reduce 3″ 14‴ into time, as 15° is to 60′, ſo is 3″ 14‴ to 12‴ of time; now, as the northern magnetic point moves faſter than the earth, 23h. 56′ 4″—12‴=23h. 56′ 3″ 48‴ for the ſidereal revolution required.

PROBLEM XIII.

HAVING the periodical revolution of the magnetic points given, to determine their annual rate of revolution.

Example I. THE periodical revolution of the northern magnetic point being 1096 years; as 1096 years is to 360°, ſo is 1 year to 19′ 42″ 29‴, the annual rate of the northern magnetic point.

Example II. The periodical revolution of the ſouthern magnetic point being 2289 years; as 2289 years is to 360°, ſo is 1 day to 9′ 26″, the annual rate of the ſouthern magnetic point.

PROBLEM XIV.

To find the ſituation of the firſt and laſt magnetic meridian for any given time.

Rule. Firſt find the place of the two magnetic points, by their rate of revolution, for the time required. Secondly, find either of the two magnetic nadirs, which are oppoſite to the two magnetic points. Thirdly, draw a circle through theſe three points, this will always be a great circle, and it will naturally be divided into two arches by the magnetic pointer axis, which is a right line paſſing from one magnetic point to the other. The greateſt arch will always be the firſt magnetic meridian from which all the others are numbered; the leaſt arch will be the laſt magnetic meridian.

Example. Let DE, fig. 1. repreſent the two magnetic points, then a point G being found on the ſurface of a globe diametrically oppoſite to E, this will be the northern magnetic nadir. A circle being drawn through theſe three points, as its plane, will paſs through the centre of the earth C, it will be a great circle. If the magnetic pointer axis DNE is drawn, DKE will repreſent the firſt magnetic meridian, from which all the others are numbered, and DIE will repreſent the laſt magnetic meridian.

PROBLEM XV.

Having the ſituation of one magnetic point, and one magnetic nadir given, to determine the ſituation of the magnetic equator for any given time.

Example. If we find a ſituation on the Chart in the northern hemiſphere, equally diſtant from the magnetic pole and magnetic nadir, a great circle being drawn every way ninety degrees from the magnetic pole, will be the magnetic equator, on which the magnetic meridians are all numbered.

PROBLEM XVI.

Having the latitude and longitude of a place given, to determine by the chart the variation of the compaſs.

Example. Let it be required to know the variation of the compaſs in the latitude of 40 degrees north, and longitude 170 eaſt from Greenwich, after finding where this meridian and parallel meet on the Chart of the northern hemiſphere, the angle between the magnetic meridian and the earth's meridian being meaſured at this place, this angle is equal to the variation of the compaſs.

PROBLEM XVII.

Having the variation of the compaſs, and latitude of the place given, by the chart to determine the longitude.

Example. A Ship in the Atlantic Ocean, ſailing in the latitude of 50° north on a voyage from Philadelphia to London, it is required to know when ſhe is within twenty degrees of the meridian of Greenwich. The angle is meaſured on the chart between the twentieth meridian from Greenwich and the magnetic meridian in the latitude of 50° north, and when the accurate obſerver in the ſame latitude finds the variation, by obſervation, equal to the angle meaſured on the chart, he knows himſelf to be 20° from the meridian of Greenwich.

PROBLEM

PROBLEM XVIII.

Having the latitude of the place, the north polar diſtance, and the longitude of the northern magnetic point given, from the following table, to determine the variation by calculation for the year 1722.

Example.

Co. lat. Greenwich 38° 31′ 20″ = 38° 31′ 20″
North polar diſt. 30° 55′ 0″ = 30° 55′ 0″

Sum 69° 26′ 20″ dif. 7° 36′ 20″ E. lon. n. mag. p. 168° 10′

½ Sum 34° 43′ 10″ ½ dif. 3° 48′ 10″ ½ lon. mag. point 84° 15′

As ſine	-	34° 43′ 10′	-	9.75551
Is to ſine	-	3° 48′ 10′	-	8.82134
So is co-tangent	-	84° 15′ 0′	-	9.00301
				17.82435
To tangent		0° 46′ 0″		8.06884
As co-ſine	-	34° 43′ 10″	-	9.91486
Is to co-ſine	-	3° 48′ 10″	-	9.99904
So is co-tangent	-	84° 15′ 0″	-	9.00301
				19.00205
To tangent		6° 58′ 0″		9.08719

6° 58′ — 46′ = 6° 12′ eaſt variation

REMARK.

REMARK.

As the foregoing is the method by which all the ſubſequent calculations are made, one example will be ſufficient: the reader will find in the following table the variations, both by calculation and obſervation, which differ but a few minutes from each other. As the calculations are made for Greenwich, and the obſervations generally made in London, they could not be expected to agree much nearer, ſeeing the firſt magnetic meridian did not always paſs the ſame diſtance from that Royal Obſervatory.

A TABLE of the Place of the northern magnetic Point, as it is found to perform a Revolution round the north Pole of the Earth, at the rate of 19′ 42″ 29‴ of Longitude each year, exhibiting the Variation by Calculation and Obſervation.

Anno. Dom.	Longitude of Magnetic Point.			Variation by Calculation.		Variation by Obſervation.				Difference.		
1622	168°	30′	E	6°	12′	6°	0′	0″	E	0°	6′	0″
1630	171	7										
1633	172	7		4	20	4	5	0		0	15	0
1640	174	24										
1650	177	42										
1657	180	0		0	0	0	0	0		0	0	0
1660	179	0	W									
1665	177	22		1	27	1	22	30	W	0	4	30
1670	175	43										
1672	175	4		2	42	2	30	0		0	12	0
1680	172	26										
1683	171	27		4	41	4	30	0		0	11	0
1690	169	9										
1692	168	30		6	18	6	0	0		0	18	0
1700	165	52		7	44	7	45	0		0	1	0
1710	162	35										
1717	160	17		10	45	10	42	0		0	3	0
1720	159	18										
1724	157	59		12	0	11	45	0		0	15	0
1725	157	39		13	30	11	56	0		0	26	0
1730	156	1		13	2	13	0	0		0	2	0
1735	154	22		13	55	14	16	0		0	21	0
1740	152	44		14	34	15	40	0		1	6	0
1745	151	5		15	39	16	53	0		1	14	0
1750	149	27		16	32	17	22	0		0	50	0
1760	146	10		18	15	19	12	0		0	57	0
1765	144	31		19	6	20	0	0		0	54	0
1770	142	52		19	57	20	35	0		0	0	0
1780	139	35										
1790	136	18										
1794	135	0		23	56	23	56	0		0	0	0
1795	134	40										
1796	134	20										
1797	134	0										
1798	133	41										
1799	133	21										
1800	133	1										

C H A P. III.

THE OBJECTION OF FALSE VARIATION REMOVED.

SEVERAL objections have been ſtated againſt making accurate obſervations of the magnetic variation at ſea.

Objection 1ſt. THE ſame compaſs has been ſaid to give a different variation, from no other cauſe than putting the ſhip's head a contrary way.

Anſwer. THIS might readily happen, if there was more iron near the compaſs on one ſide of the ſhip than on the other; the following remedy is propoſed for this difficulty. Let there be fixed a true meridian on ſhore, but near the ſhip, out of the reach of the attraction of iron; here let the variation be taken on this meridian; then, before ſhe ſails, let the variation be taken on board the ſhip, with her head turned, if occaſion ſhould require, on every point of the compaſs; by noting the difference between the true variation on the true meridian, and the falſe variation on board, a table of difference may be conſtructed, which may ſhew the allowance neceſſary to be made for falſe variation throughout any voyage, while the iron remains in the ſame ſituation. Or, if the azimuth compaſs is firmly fixed to a three-legged ſtaff, about five feet above the deck, it will then be nearly out of the reach and influence of the iron.

Objection 2d. THE ſame compaſs removed a few miles, but at a different time of the day, has been ſaid to give variations differing from one another.

Anſwer. As it is impoſſible to move, either on the ſame meridian or parallel of latitude, without having a different variation, it is not ſtrange if there ſhould be a ſenſible difference in a few miles: beſides, if the obſervations are made at different times of the day, the ſmall diurnal variation, which ſeems reducible to certain fixed laws, will require to be allowed for.

Objection 3d. THE ſame compaſs, on the ſame day, and in the hands of the ſame obſerver, has been ſaid to give variations differing from one another, on board the ſame ſhip, when under ſail, and when at anchor in a road-ſtead.

Anſwer. A SHIP being under way muſt certainly change her ſituation; if the variation was not different in different places, it would be hard to know the ſituation of the place by the variation; therefore, one anſwer may apply to both the ſecond and third objections.

Objection 4th. COMPASSES made by the ſame artiſt, at the ſame time and place, but on board different ſhips, have been ſaid to differ in the variation.

Anſwer. THIS might ariſe from a greater quantity of iron in one ſhip than another, placed in ſuch a ſituation as to give a falſe variation to the needle.

Objection 5th. THE ſame compaſs on board the ſame ſhip, and within a few miles of the ſame ſituation, but at different times of being in ſuch ſituation, is ſaid to have given different variations.

Anſwer. THE two magnetic points being known to perform revolutions, the variation muſt of conſequence continually alter more or leſs in every part of this globe; therefore the different variation may readily be accounted for, as well from the difference of time as the different ſituations of places.

Objection 6th. DIFFERENT compaſſes, at the ſame time, on board the ſame ſhip, and in every reſpect under the ſame circumſtances, are ſaid to have given variations differing from one another.

Anſwer. DIFFERENT compaſſes, if true, are found to agree with one another on ſhore. I knew an inſtrument-maker in particular, who had a meridian on ſhore, and made many circumferenters. He made a rule never to turn one out of his hands, till he proved it by his meridian. By this method all his inſtruments would agree one with another.

CAPTAIN Cook, when he obſerved the tranſit of Venus at the Iſland of King George III. or Otaheite, although he found in ſome inſtances, that different inſtruments gave different variations, yet in the account of his voyage he writes, "the ſame needle agrees with itſelf "in ſeveral trials one after another." This ſeems to prove what dependance may be placed upon a true needle. The cauſe of different in-

ſtruments

ſtruments diſagreeing muſt then be occaſioned by a fault in the workmanſhip.

Hitherto it has generally been thought uſeleſs to try to obtain the variation with a great degree of accuracy, merely for the purpoſe of ſteering the courſe of a ſhip; but in order to make the variation ſcheme uſeful in finding the ſituation of a ſhip at ſea, it will be neceſſary, in order to counteract the motion of the waves, to make a number of obſervations with great care, and take a mean for the true variation. In this reſpect a little practice will point out the path towards perfection.

It is well known that on land there is no difficulty in determining the longitude by Jupiter's ſatellites, if the true ſituation of any coaſt, and the ſituation of the two magnetic points are known, the true variation may be found by calculation; ſo that if bodies of iron ore, upon the ſea-coaſt, ſhould even influence the needle, the difference between the variation, by calculation and obſervation, will conſequently be the allowance for falſe variation. By this method the variation may be corrected with a little care.

It is probable the magnetic obſervations, in Captain Cook's laſt voyage, are ſtill as accurate and extenſive as any other yet publiſhed; but as the variation of the compaſs is ſubject to change, the length of time between Captain Cook's laſt obſervations, and the time for which the charts are conſtructed, will cauſe ſome difference, unleſs the proper allowance is made.

CHAP.

CHAP. IV.

HINTS CONCERNING THE CAUSE OF THE MAGNETIC VARIATION.

NOTICE has been already taken, in the Introduction, of the Hypotheſis of Dr. Halley, with which he attempted to account for the magnetic variation, by four magnetic poles. From a multitude of magnetic obſervations, made as well in Dr. Halley's day as ſince, it is found that the firſt and laſt magnetic meridians are always arches of great circles. If there were, according to Dr. Halley four magnetic poles, two fixed, and two moveable, they could never admit any one magnetic meridian to be an arch of a great circle, unleſs all the ſaid four poles were ſituated in the ſame plane; and as the two magnetic poles or points move round the poles of the earth at different periods, the two fixed poles of our earth, which Dr. Halley ſuppoſed were magnetical, could never continue in the ſame plane with thoſe two moveable magnetic poles. Hence it muſt follow, that there are but two magnetic poles or points, and that the poles of this earth have no more influence on the magnetic needle than any other part of the earth.—Now there muſt neceſſarily be a cauſe for the needle's having an univerſal direction towards theſe two magnetic points; and this cauſe muſt either be above or below the ſurface of the earth. Dr. Halley ſuppoſed the cauſe to be a nucleus or inner globe, included within our globe, with a fluid medium between. The motion of the inner globe he thought to be communicated by the outer one. While the motion of the magnetic influence was ſuppoſed to be weſtward, there was ſome degree of reaſon for Dr. Halley to account for the variation as he did; but, as it is now determined without the leaſt doubt, that the northern magnetic point moves faſter than the earth, from weſt to eaſt, the caſe ſeems entirely altered.

It is an eſtabliſhed axiom, that "no cauſe can give what it has not "itſelf:" how then can the earth give a ſwifter motion than it has itſelf to a nucleus therein contained. The northern magnetic point revolving quicker, and the ſouthern ſlower, than the earth, the apparent revolution of the northern one muſt be from weſt to eaſt, while the apparent revolution of the ſouthern one is the contrary way. Whereas, if the variation of the variation was occaſioned by a nucleus, Dr. Halley's two moveable magnetic poles ſhould move the ſame way, and with equal velocities.

To determine the periods of the magnetic points, it was neceſſary to know their true ſituations for different times. If the exact latitude of the magnetic points were well known, it would be eaſy to fix their longitudes. To fix their places properly, it was neceſſary to have more obſervations made near the firſt and laſt magnetic meridians. But I conceive the beſt mode of proving the places of the magnetic points would be to make aſtronomical obſervations on the ſpot. Seeing navigators have often been in much higher latitudes, it would be very eaſy to approach the magnetic points; for example, the northern one might be found by following the horizontal needle till it became indifferent to any particular direction; or it might be found by the inclination of the dipping needle. With a view of viſiting the northern magnetic point in particular, as this expence would fall heavy on an individual, I have ſeveral times endeavoured to deſcribe the importance of ſuch a voyage; firſt to the American Congreſs; and again to the Board of Longitude in Great Britain; apprehending ſuch an expedition would caſt light on this myſterious principle, as it might go near to determine the cauſe of the variation, and pave the way to other uſeful diſcoveries; but as I have not hitherto been fortunate enough to ſucceed in undertaking this expedition myſelf, I would beg leave earneſtly to recommend this matter to the particular attention of the gentlemen who, under the Britiſh Government, have the direction of the ſurvey of the north-weſt coaſt of America. The preſent King of Great Britain having diſtinguiſhed himſelf ſo eminently in the cauſe of Science, I hope this matter will not be unworthy their attention.

Let the cauſe of the magnetic variation be what it may, it is very remarkable that the ſidereal revolutions of the two magnetic points are regularly performed in the ſame way, and are alſo very nearly equal in time to the neareſt ſatellites of ſeveral of the planets; for inſtance, the nearest of Saturn's, according to Dr. Herſchell, performs one ſidereal revolution in 22h. 40′ 46″.

CHAP. V.

CONCERNING THE CONSTRUCTION OF THE CHARTS.

THE Charts are conſtructed in ſuch a manner, that, if the blank gores were cut out, the remainder would fit and cover a globe forty-eight Engliſh inches in circumference. This method of projecting the ſphere with the magnetic meridians will be found to preſerve the true proportions of each country, and will probably ſhew the nature of the curves formed by the magnetic meridians better than Mercator's projection, on which the Halleyan lines are delineated; and the preſent projection may ſerve not only for Charts, but for covering globes.

THE earth's meridians meeting in the poles of the earth, the magnetic meridians meet in the two magnetic points, experience proves that the influence of one magnetic point is greater than the other; on this account, the magnetic meridians are not curves truly circular, except the firſt and laſt, which are arches of great circles. The nature of the curves being known, the proportion of influence is alſo known, and the curves will always be included within the moſt rigid rules of calculation.

To fix the places and periods of the magnetic points, thouſands of calculations have been made, that do not appear in the preſent work; as they were made merely for trial, it is unneceſſary to make them public.

In a former publication I propoſed a magnetic Almanack, which will contain an univerſal ſet of tables, ſhewing the variation correſponding with any part of each meridian, without the trouble of meaſuring angles; ſuch tables, when the places and periods of the magnetic points are proved to be true, and the theory ſettled, will afford a ready means of applying the principles to practice; but if by future experience the places and periods of the two magnetic points ſhould not be found very exact, at preſent this will no doubt be deemed pardonable, ſeeing the exact length of a year has not been long determined, notwithſtanding the many volumes of aſtronomical obſervations made during many centuries.

Because the variations, in Europe and America, have been formerly obſerved to be nearly equal in the ſame latitude, ſome have ſuppoſed the variation to be the ſame all acroſs the Atlantic. Actual obſervations, carefully made at the preſent time, will prove this not to be the caſe; for, in ſailing weſtward from Great Britain, the variation increaſes amazingly, till it comes to the greateſt; and decreaſes again rapidly before we touch upon the coaſt of the new world: the change being ſo very great in ſailing a ſingle degree, it is hoped the obſervation, when well made, will be very uſeful.

CHAP. VI.

HYPOTHESIS CONCERNING MAGNETIC TIDES.

BESIDES the memorable deluges of Noah, Ogyges, and Deucalion, there are innumerable other accounts of the waters of the ocean making remarkable encroachments on the land, and returning to their former bounds again. To publiſh a full hiſtory of theſe inundations would require many volumes.

After conſulting a multitude of theſe accounts, they ſeem to take place according to the revolutions of the two magnetic points; for, while the magnetic points approach the meridian of any place, the ſea ſeems to gain upon the land; and the contrary, when the magnetic points recede from any place. This appears evidently to be the caſe at the preſent time; if ſo, there is reaſon to ſuppoſe this alſo to have been the caſe in former times, although ſome of the ancient accounts of this ſort ſeem to be deficient, in not fixing the epocha in which theſe changes have happened.

The Chineſe Emperor Xunus was full of trouble on account of the high waters, which threatened to overflow the lower parts of his Empire; after many experiments, he gave command to one Quenius, to caſt up a bank againſt the ſame; but he not being able to perform it, and leaving the ſame imperfect, the charge of the work was committed to his ſon Yvus, who, in the ſpace of thirteen years, effected it, to the great accommodation of the inhabitants. He followed his deſign all that time with ſuch earneſtneſs that he would hardly eat or ſleep. Some part of this great and ſtupenduous work, it is ſaid may be ſeen at the preſent day.

Diodorus Siculus, in his fifth book, gives an ancient ſtory, current among the Samothracians, of a great deluge that overflowed a good part of the coaſt of Aſia, and the lower grounds of its Iſlands, when the Euxine Sea firſt broke open the Thracian Boſphorus, and Helleſpont, and overflowed all the adjacent country.

Many of the moderns believe, that the accounts of the Great Iſland of Atlantis, mentioned in the Timaeus of Plato, from the obſcure tradition of Egyptian prieſts, is not altogether fabulous; and that America agrees with the ancient deſcription thereof. At that time the account ſays, the Atlantic Sea was navigable, and had an Iſland before the Pillars of Hercules; that this Iſland was greater than both Lybia and all Aſia together, and afforded an eaſy paſſage to other neighbouring iſlands. In proceſs of time, it is ſaid, this great Iſland of Atlantis, being abſorbed in the Sea, entirely diſappeared.

I SHALL not attempt to decide on the probability of the continent, now called America, being known to the ancients; but it ſeems remarkable, that the name *Chuchum-atlanes* ſhould ſtill be preſerved in the Spaniſh territory in America, with a termination ſo nearly ſimilar to the ancient name of that iſland. In a large map of the Weſt Indies (dedicated to the King of Great Britain) by Captain Joſeph Smith Speer, and in ſeveral other maps, it is placed in about the latitude of 16° north, and longitude 93° 30′ weſt from Greenwich. If this name is derived from the ancient inhabitants of the iſland of Atlantis, it would ſeem that the whole of that great iſland was not deſtroyed by the ocean, but that ſome of the inhabitants retired to the high grounds, till, by degrees, the waters of the ocean retired.

THE Abbé Raynal, and others are firmly of opinion, that America has emerged from the ocean ſince the old world, for the following reaſons.

THE broad and long rivers, the ſpacious lakes and vaſt moraſſes, to the north; the immenſe foreſts to the ſouth; the almoſt eternal ſnows between the tropics; no men entirely black; very fair people under the line; a cool and mild air in the ſame latitude as the ſultry uninhabitable parts of Africa; and, laſtly, a difference of ten and twelve degrees in the temperature of the old and new hemiſpheres; theſe ſays he, are ſo many tokens of a world that is in a ſtate of infancy.

IN Evans's firſt map of the American Colonies we find a note, declaring, that there are glaring marks of a deluge in America, of a more recent date than thoſe of the old world.

THESE conjectures are ſtrengthened by Don Ulloa, from the prodigious quantities of ſea-ſhells, mentioned in his voyage to South America, and found far above the preſent reach of the ſea.

IN the 18th Chapter of the Syſtem of Geography by Varenius, improved and illuſtrated by Sir Iſaac Newton and Dr. Jurin, many memorable inſtances are recorded, where the ſea has encroached at one time, and the contrary at others.

THE inhabitants of Ceylon ſay, their iſland was formerly ſeparated from India; and this is very likely. In modern times, according to Buffon, the ſea has encroached 30 or 40 leagues on the northern coaſt of Ceylon.

The Iſland of Sumatra is ſaid once to have joined Malya. It is believed it was the golden Cherſoneſus, and was accounted a peninſula.

The Indians, on the Malabar coaſt, tell us that the Maldivia Iſlands were formerly joined to India; but now they are ſaid to be divided into eleven thouſand iſlands. The ſea, encroaching, has covered the low grounds, and turned the high grounds into iſlands. Strange ſtories have been told of the Maldivia nut growing at the bottom of the ſea. Garcias thought the trees, that bare thoſe nuts, were of old time, together with the land on which they grew, overwhelmed by inundations, and afterwards caſt up by the working of the waves.

Varenius is of opinion, that all the Oriental Iſlands, between Aſia and the Streights of Magellan, have been occaſioned by the ſeas breaking in violently on the land, and ſeparating one part from another.

Language, ſays Dr. Johnſon, is the pedigree of nations; all the inhabitants of the Iſlands, ſcattered over the great Pacific Ocean, ſpeaking a dialect of the ancient Malay language, proves that theſe people are of the ſame nation. As they know ſo little of each other, and are unacquainted with navigation, it ſeems unlikely they ſhould be ſcattered ſo many thouſand miles aſunder, if theſe Iſlands had not been part of the ſame continent. May they not be the ſcattered remains of one great country? and might not the ſea, by its encroachments, have covered the low grounds, and turned the tops of mountains into iſlands?

The accounts of ancient geographers, concerning Aſia, prove that continent formerly to have extended much further eaſtward than at preſent. Greek writers deſcribe the provinces, eaſtward of the River Ganges, as regions of immenſe extent. Cteſias affirmed, that India was as large as all the reſt of Aſia. Oneſicritus, whom Pliny the naturaliſt follows, contended that it was equal to a third part of the habitable earth. Nearchus aſſerted, that it would require four months to march, from one extremity of it to the other, in a ſtraight line.

According to the Abbé Raynal, the late obſervations of Engliſh navigators have put it almoſt beyond doubt, that all the iſlands in the South-Sea formerly compoſed only one continent.

Buffon concludes, that, from Kamtſchatka to New Britain, the ocean has encroached on theſe coaſts to the extent of 400 leagues; of courſe, the bounds of the old continent do not ſtretch ſo far eaſtward as at a former period.

Ancient writers ſay, that Sicily once joined Italy; and that the Iſland of Eubæa, or Negropont, joined Greece: that great revolutions of this kind are daily going on, is evident by undeniable monuments, which the attentive obſerver of nature every where diſcovers; ſea-ſhells of all kinds, and corals, entire or broken, being found laid up in order in every quarter of the globe, in places the moſt diſtant from the ocean, in the bowels of the earth and on the tops of mountains.

Strabo ſays that, in his time, the eaſtern part of Britain was viſible at the River Rhine, which was then called the Helius: if ſo, the diſtance could not be more than ſix or ſeven leagues. This alſo appears evident from the old map of Cellarius.

The map of Great Britain, by Ptolemy, deſcribes the northern part thereof to run out in the form of a promontory full four degrees farther eaſtward than the land at preſent is found to extend.

What Ovid ſays on the ſubject of changes is well known,

"I've ſeen the ſolid earth transform'd to ſea,
"And water alſo turn'd to ſolid land;
"While fiſhes ſhells far from the ocean lie,
"And ruſty anchors on the mountains top!"

All theſe circumſtances demonſtrate, that the limits of the ocean have never been inſurmountable; and that, by continually changing the face of the globe, it has alternately taken away the land, and reſtored it to its inhabitants.

The Hiſtory of the Pariſian Academy mentions a maſs of ſea-ſhells diſcovered below ground 130,680,000 cubic fathoms, either whole or in fragments, without the leaſt mixture of ſtone, earth, ſand, or other foreign matter. This prodigious maſs lies in Turenne, more than thirty-ſix leagues from the ſea, and muſt prove that country to have been covered by the ocean for ages, to accumulate ſuch a quantity.

Among the Memoirs of the Royal Daniſh Academy, vol. IV. is one to prove that the Baltic Sea, when the principal inhabitants of Norway and Sweden emigrated from Aſia, did not cover the ground it does at preſent. There the waters of the ocean continue to encroach on the ſhores at the preſent time, having deſtroyed and overwhelmed, among many others, the famous port of Vineta, and covered, by ſlow degrees, a large portion of Pomerania.

The Princeſs de Daſchkaw, in one of the letters ſhe has favoured me with, remarks that "Vineta, on the coaſt of Pomerania, was ſome "centuries ago one of the moſt flouriſhing mercantile towns in Ger-"many; at preſent its ruins, which are often to be ſeen under water, "are the ruin of many a ſhip. It is univerſally believed, that the "ſame revolution, by which Vineta was overwhelmed, ſevered alſo "the Iſle of Rugen from the German continent, of which it was till "that time the moſt northern point."

In the ſame manner the ſea, by waſhing the coaſt of Norway, is well known to have detached ſeveral little iſlands from the main land, and is ſtill making daily depredations on the continent. The German ocean, encroaching by degrees upon the ſhores of Holland, near Catt, overwhelmed the ruins of an ancient citadel of the Romans, which had formerly been built on that coaſt, and which is now actually under water.

At Rome, according to M. de la Condamine, the tide often overflows the pavement of the Pantheon, and it cannot be ſuppoſed the Romans would have built that Temple on a ſpot that was then ſubject to inundations.

Venice is now diſtant only five miles from the continent, but was formerly, according to Guiotti, ten miles from it; yet as the ſea thereabout is now riſing, it may again be further from the continent than ever.

In a Hiſtory of the Earth and animated Nature, Dr. Goldſmith remarks, that the country round the Iſle of Ely, in the time of the Venerable Bede, about a 1000 years ago, was one of the moſt delightful ſpots in the whole kingdom. It was not only richly cultivated, and produced all the neceſſaries of life, but grapes alſo, that afforded the moſt excellent wines. The accounts of that time are copious in the deſcription of its produce and fertility. But about the time the northern magnetic point was laſt on the ſame ſide of the earth as Great Britain, the ſea broke in upon the land, and overwhelmed the whole country, and totally deſtroyed one of the moſt beautiful vallies in the world.

ABOUT the ſame time happened a mighty inundation, which extended to Flanders, whereby a great part of that country was laid under water; and many of the diſtreſſed people bereft of their habitations, came over to England. King Henry the firſt taking compaſſion on their diſtreſſed condition, and alſo conſidering that they might be beneficial to his ſubjects, by inſtructing them in manufactures, firſt ſettled them about Carliſle, and afterwards removed them into South Wales.

THEN it was that a large eſtate, the patrimony of Earl Goodwin, was overflowed at the place which is now called Goodwin Sands.

IN a ſurvey of Cornwall, Carew affirms, that the ſea has ſwallowed up the whole county of Lioneſs; and that there was ſuch a county, he ſufficiently proves by many cogent reaſons. Camden, out of Gyraldus, reports that anciently a great part of Pembrokeſhire ran out, in the form of a promontory, towards Ireland, as appears by the ſpeech of King William Rufus, that he could eaſily with his ſhips, make a bridge over the water, now called Saint George's Channel; ſo that he might paſs on foot from thence to Ireland.

THE Country round the Iſle of Ely continued to be covered by water, as before mentioned, for many years, till the time the northern magnetic point had paſſed the meridian of the place, when the ſea, from the ſame cauſe which had prompted its invaſions, began by degrees to abandon the earth in like manner.

THE ocean ſeems to have retired round England, and the neighbouring countries, till the northern magnetic point, according to its rate of revolution, was on the oppoſite ſide of the earth from England; for it appears by an account of the inſtitution of the Royal Society, that, in the year 1663-4, the ways and means of raiſing a revenue being conſidered,

dered, a member of that learned body, of the family of Howard, propoſed ſoliciting the King for a grant of ſuch lands as the ocean had deſerted.

Hubert Thomas, ſometime chief Secretary to Frederick Count Palatine of the Rhine, and Prince Elector, in his deſcription of the country about Liege, ſays that the ſea hath come up to Tongres, now near an hundred miles from it. Guicciardin, it is true, could hardly believe it; but Verſtigan and others were of the ſame opinion with Hubert Thomas, and thought the reaſons for his aſſertion were good; one, among others was, that the great iron rings were then remaining, unto which the ſhips were formerly faſtened.

Anchors having been found in digging on the heath in Brabant, ſeems to prove that place to have been covered with the ocean, and that not many hundred years ago; for had it been at a very early period, the anchors before now muſt have been conſumed with ruſt.

The two magnetic points approaching the meridian of Greenwich, at the preſent time, it appears both from obſervation and information, that the ocean continues to make rapid encroachments on the land; at leaſt, on every part of the ſea coaſt of Europe; and, I think, too rapidly to keep pace with the preceſſion of the equinoxes, which ſome have conjectured to be the cauſe of the revolution of the ocean.

What the ſea gains on one ſide of the globe, it loſes on another; but it is improbable the ſea could riſe and fall at the ſame inſtant at two different places, very near to each other. At firſt view this may appear to be the caſe, when the water grows ſhallower; but the water often grows ſhallower, or the land gains, on the ſame coaſt where the ſea riſes, owing to the earth, ſand, and other ſediment, ſettling at the bottom.

In the Pacific Ocean is a ſpace where both magnetic points have now a retrograde motion; in this ſpace the waters of the ocean continue to fall. Dr. John Reinhold Forſter, in his Obſervations during a Voyage round the World, page 146, 147, gives an inſtance, in the South Sea, where he could fairly perceive that the ground had been raiſed; or, in other words, that the waters had fallen. And Captain Cook, in deſcribing Palmerſtone's Iſlands, in the firſt volume of the account of his laſt Voyage, page 221, ſays,

"We found upon them, far beyond the preſent reach of the ſea, "even in the moſt violent ſtorms, elevated coral rocks which, on exa- "mination, appeared to have been perforated in the ſame manner the "rocks are that now compoſe the outer edge of the reef. This evi- "dently ſhews, that the ſea had formerly reached ſo far; and ſome of "thoſe perforated rocks were almoſt in the centre of the land."

In the 485th page of the 2d. volume, Captain Cook gives an account of the Peninſula at Cape Denbigh, and remarks, "It appeared to me, that "this Peninſula muſt have been an iſland in remote times; for there "were marks of the ſea having flowed over the Iſthmus. And even "now, it appeared to be kept out by a bank of ſand, ſtones, and wood, "thrown up by the waves. By this bank it was evident, that the land "was here encroaching upon the ſea, and it was eaſy to trace its gra- "dual formation."

It is highly probable theſe revolutions of the ocean are governed by laws as uniform as the common tides; if theſe laws were once fully known, we might calculate a deluge as well as the return of a comet; and it would be of the utmoſt importance in geography; for, let a map of the world be ever ſo correct, in proceſs of time, as the ocean continuing to gain in ſome places, while it loſes in others, the map becomes erroneous. And after knowing the proportion between land and ſea throughout the globe, as we know already the number of acres contained in the whole, the quantity of land emerging every year might alſo be eaſily eſtimated: this in round numbers I take to be about two millions.

If, when the northern magnetic point approaches the meridian of any place, the ocean ſhould uniformly be found to riſe, ſo as to cover the low grounds, this may be termed a magnetic tide; and if, when both magnetic points are in conjunction, the ocean ſhould riſe, ſo as to cover the higher grounds, this may be termed a magnetic ſpring tide.

However, as this laſt chapter is only a digreſſion by way of Hypotheſis, ſhould it prove contrary to future experience, this will not affect the foregoing theory, with which it is unconnected, and which admits of mathematical demonſtration.

APPENDIX.

A FEW OF THE

REPORTS, OPINIONS, &c.

RECEIVED BY THE AUTHOR,

ON THE PRINCIPLES OF THE PRECEDING WORK.

From the American Miniſter and Plenipotentiary, then at the Court of France.

Sir, *Paris, Auguſt* 8, 1787.

I HAVE duly received your favour of June 6th, and immediately communicated its contents to a member of the Academy. He told me they had received the other copy of your memorial; which you mention to have ſent through another channel; that your ideas were not conveyed ſo explicitly as to enable them to decide finally on their merit: but they had made an entry on their journals to preſerve to you the claim to the original idea. As far as we can conjecture it here, we imagine you make a Table of Variations of the needle for all the different meridians whatever. To apply this table to uſe in the voyage between America and Europe; ſuppoſe the variation to increaſe a degree in every 160 miles, two difficulties occur; 1ſt. A ready and accurate method of finding the variation of the place. 2d. An inſtrument ſo perfect as that (though the degree on it ſhall repreſent 160 miles) it ſhall give the parts of the degree ſo minutely as to anſwer the purpoſes of the navigator. The variation of the needle at Paris actually is 21° W. I make no doubt but you have provided againſt the doubt entertained here, and I ſhall be happy that our country may have the honour of furniſhing the old world with what it has ſo long ſought in vain. I am, with much reſpect,

SIR,

Your moſt obedient humble ſervant,

Mr. John Churchman. T. JEFFERSON.

Entry on the Journals of the Academy of Sciences at Paris.

LA lettre de M. Churchman, de Philadelphie, ſur la variation de l'aiman, a eté lue à l'Academié des Sciences de Paris, le 16 Juin, 1787.

JE certifiè cet extrait conforme aux regiſtres de l'Academié à Paris, le 15 Septembre, 1789.

LE MARQUIS DE CONDORCET.

From Sir Joſeph Banks, Bart. Preſident of the Royal Society of London, &c.

SIR, *Soho-Square, September 1ſt,* 1787.

I HAVE received your ingenious letter relative to the variation of the needle, and take the liberty of adviſing you to purſue, with diligence, a ſubject on which it appears to me you have made a progreſs, ſufficient to authorize a reaſonable hope, that ſcience will derive real increaſe from your labours.

THE Royal Society having lately removed into a new houſe, the firſt ſeries of obſervations relative to the variation is only now in its courſe. I cannot therefore tell you with the utmoſt preciſion what the variation is there, our inſtrument at preſent gives 23° 8′ weſt, which probably is ſufficiently exact for your purpoſe: preſently, when the inſtrument is moved, we ſhall find if the magnetiſm of the building has any material effect upon it; of which, if it has, I ſhall with pleaſure inform you. I am,

SIR,

Your obedient and moſt humble ſervant,

Mr. John Churchman. JOSEPH BANKS.

From the Legiſlature in Maryland, dated at Annapolis, in December 1787.

SIR,

I AM commanded by the Honourable Houſe of Delegates, to return you their thanks, for your communication and explanation of your ideas relative to the principles of magnetiſm, and their application in regulating the Surveys of Land; and I with pleaſure return you the thanks of the Houſe accordingly.

I am, &c. &c.

To John Churchman,
Eſquire.

THOMAS C. DEYE,
Speaker of the Houſe of Delegates.

From Sir H. Parker, Bart.

SIR, *Admiralty, 20th December, 1787.*

I HAD the honour, at the meeting of the Commiſſioners of the Longitude, the 8th of this month, to lay before them the memorial you ſome time ago tranſmitted to me, ſtating, that you have diſcovered certain fixed principles in magnetiſm which will aſcertain, to a great preciſion, the longitude of places in all parts of the globe, &c. and I am directed to acquaint you, the Board have the ſubject matter of your ſaid memorial under conſideration, and will take an early opportunity of giving you their ſentiments upon what you have ſubmitted to them. I am,

SIR,

Your moſt humble ſervant,

H. PARKER,

Secretary to the Commiſſioners of the Longitude.

REMARK.

THE next Letter I was favoured with, from the Britiſh Board of Longitude, was dated 6th of March, 1788. This contains information concerning the magnetical Memoir of Profeſſor Leonard Euler, publiſhed at Berlin in the year 1757, and mentioned already in the introduction. Each plan propoſed for the ſolution of this problem conſiſts of two parts. 1ſt. The means, 2d. The method. The lunar method being by means of the ſun or ſtars, and the moon; and the magnetic method, by means of the two magnetic points. If Profeſſor Euler only by diſcovering there were but two magnetic poles, or points, diſcovered the magnetic method, without fixing the latitudes, longitudes, revolutions, or courſes of the two magnetic points; might it not by the ſame rule be ſaid, that he who firſt diſcovered the ſun and moon, diſcovered alſo the lunar method. But the lunar method was imperfectly known before Sir Iſaac Newton laid down the true theory of the moon; after which Profeſſor Euler reduced the theory to elegant algebraical expreſſions; of which Tobias Mayer availing himſelf, he was by a very ſingular addreſs enabled to bring out the maximum to a conſiderable degree of exactneſs. Yet the lunar method was of but little uſe before the Nautical Almanac was planned by Doctor Maſkelyne, the Aſtronomer Royal, and publiſhed under the direction of the Board of Longitude; nevertheleſs the anſwer of the Board was very proper for that ſtage of the buſineſs. Seeing the

Board were not then in poſſeſſion of my calculations. The object of my firſt memorial was merely to introduce the ſubject to their notice, with an intention of bringing forward my demonſtrations at a future day.

◆

Report of a Committee of the American Congreſs, publiſhed in the Journal.—In the houſe of repreſentatives of the United States, Monday 20th of April 1789.

Mr. TUCKER reported from the Committee, to whom was referred the petitions of John Churchman and David Ramſey *; that the Committee had, according to order, the ſaid petitions under conſideration, and agreed to report thereupon: which he delivered in at the Clerk's table, where the ſame was twice read, and debated by clauſes: the firſt clauſe, in the words following—To wit, "The Com-" mittee have conferred with Mr. Churchman, and find he has made " many calculations, which tend to eſtabliſh his poſition, that there are two " magnetic points which give direction to the needle. That, upon this " doctrine, he has endeavoured to aſcertain, from a given latitude and " a given variation, what muſt be the longitude of the place; and, " having applied his principles to many inſtances in Cook's Voyages, " has found the reſult to correſpond with conſiderable accuracy with " the real facts, as far as they could be determined by the reckoning of " the ſhip. That the object, to which Mr. Churchman's labours are " directed, is confeſſedly of very high importance, and his ideas on " the ſubject appear to be ingenious. That with a view of applying " them to practice, he has contrived a map and a globe, whereby to " ſhew the angles which are made by the interſection of the real and " the magnetic meridians, in different parts of the earth. That he is " alſo engaged in conſtructing tables, for determing the longitude at " ſea upon magnetic principles. That the Committee are of opinion, " that ſuch efforts deſerve encouragement; and that a law ſhould paſs " to ſecure to Mr. Churchman, for a term of years, the excluſive pecu-

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* The petition of Dr. David Ramſey related to his celebrated Hiſtory of the Revolution.

" niary emolument to be derived from the publication of theſe ſeveral " inventions," was read: and, on the queſtion being put thereupon, agreed to by the houſe.

The ſecond clauſe in the words following, to wit: " With reſpect " to the voyage, propoſed by Mr. Churchman, to Baffin's Bay, the " Committee are cautious of recommending, in the preſent deranged " ſtate of our finances, a precipitate adoption of a meaſure, which would " be attended with conſiderable expence: but they are of opinion, " that, at a future day, if Mr. Churchman's principles ſhould be found " to ſucceed in practice, it would be proper to give further encou" ragement to his ingenuity," was again read: and, on a motion made, ordered to lie on the table.

On motion, ordered, " That a bill or bills be brought in, making " a general proviſion for ſecuring, to authors and inventors, the ex" cluſive right to their reſpective writings and diſcoveries; and that " Mr. Huntington, Mr. Cadwallader, and Mr. Contee, do prepare and " bring in the ſame."

Extract from the Journal.
JOHN BECKLEY, Clerk.

Extract of the Opinion of Profeſſor Van Swinden.

" TO determine the longitude, by obſervations on declination, is a great undertaking, and worthy of all our encomiums. Navigators are moſt intereſted in its good ſucceſs. This ſucceſs depends, I think, upon the complete ſolution of theſe two very intereſting problems: Firſt, to determine by theory what muſt be, at a given time, the declination of the magnetic needle, for every point of the globe; or for every place, whoſe longitude and latitude are given. Secondly, in a place whoſe latitude is given, the declination at a certain time being known, to conclude its longitude, by comparing the ſaid obſervations with the theory.

" The firſt problem conſiſts of two parts; the one purely mathematical, the other phyſico-mathematical; becauſe it is a queſtion to draw from the obſervations the chief data, upon which the real calculations are to be founded.

"I AM ſure thoſe, who apply themſelves on the diſcovery of general laws of variations, do a very uſeful work; becauſe, by thoſe means, the general cauſe, and the influence of the peculiar ones, will be better known. Beſides, it is not impoſſible at all, to come by multiplied enquiries to a knowledge of thoſe laws."

Report made to the Marine Society in Philadelphia.

GENTLEMEN,

YOUR Committee appointed the firſt Monday in April laſt, for the purpoſe of waiting upon Mr. John Churchman, agreeable to a requeſt contained in his letter to the Society; make report, that they have had a conferrence with Mr. Churchman, who communicated to them a plan and chart, which he was preparing, as well as tables, for the purpoſe of aſcertaining the longitude, from the variation of the needle, by two magnetic points revolving in orbits; and we, having conſidered the ſame, are of opinion, that it is a work of great merit, and may be of material uſe in Navigation; but the certainty of its effects depends upon experience. Upon the whole, we think it worthy of patronage, and therefore take the liberty of recommending it to the Society.

CHARLES BIDDLE.
July 5th 1790. WILLIAM ALLIBONE.

Letter by order of General Waſhington.

SIR, *New York*, *Auguſt* 28*th*, 1790.

THE Preſident of the United States has received a copy of the Magnetic Atlas, or Variation Chart, together with the Book of explanation, which you have been ſo polite as to ſend him; and requeſts your acceptance of his thanks for the ſame.

I am, moreover ordered by the Preſident to inform you, that, being deſirous of encouraging ſuch publications as tend to promote uſeful knowledge, he requeſts you will conſider him as a ſubſcriber to your Work.

I am, Sir,
Your moſt obedient ſervant,
TOBIAS LEAR.
Secretary to the Preſident of the United States.

* * *

Extract of an Opinion publiſhed January 1791, with the Reports of the George Auguſtus Univerſity at Gottingen, under the Inſpection of the Royal Society of Sciences there.

"THE explanations and propoſitions prove, that the author has "treated his ſubject very methodically."

* * *

Extract of a Letter from the Aſtronomer Royal, at Berlin, to a Nobleman at Hamburgh, dated February 5th, 1791.

"THESE reflections are produced by your ſending me the Letter, the Memoir, and Chart of Mr. Churchman. The Royal Academy had lately received duplicates of the ſame by another channel, and were engaged in examining them, with a view of giving ſome ſatisfaction to the author, with reſpect to his deſiderata. I have now the honour of ſending you, for Mr. Churchman, the report of the commiſſioners appointed to examine his work.

"M. Formey, in quality of perpetual ſecretary, had it in charge to accompany theſe papers with a congratulatory letter to Mr. Churchman; but as he is now 80 years of age, his activity is much diminiſhed. To prevent delay, I have propoſed to him to diſpenſe with this letter, taking it upon myſelf to excuſe him, in which I hope you will join your influence."

Signed, BERNOULLY.

Extract

Extract from one of the Commiſſioners' Reports made to the Royal Pruſſian Academy of Sciences and Belles Lettres, at Berlin.

"THE Academy without doubt will require, that agreeable to cuſtom, I declare my own ſentiments concerning the work, of which I am giving an account. I ſhall make no reflections on the great importance of the object on which it treats. I could only ſay, on that head, things generally admitted. Mr. Churchman is entitled to an eulogium, for having conſecrated a number of years to making reſearches on the variation of the compaſs. As a new proof of his zeal, he propoſes, as ſoon as circumſtances will permit, to make a voyage to the place where he imagines the northern magnetic point may at preſent be found. He hopes there to make important obſervations. The bare intention of the author is ſufficient to do him much honour; as to its being effected, it is, for many reaſons, worthy of attention. It was known that the two magnetic points had a motion, but Mr. Churchman is the firſt who, to my knowledge, has dared to determine this movement, and to aſſign their periodical times. This ſtep is bold, without doubt; but it is good that it is made; it will ſerve to awaken the attention of Geometricians and Aſtronomers. They may examine and diſcuſs the theory of Mr. Churchman; compare it with the new obſervations; and attempt to modify his hypotheſis, till they may approach to exactneſs, as near as can be hoped in ſciences phyſico-mathematical.

"ALTHOUGH no influence of the magnet upon the waters has till now been remarked, we may tolerate this explication, as that has been tolerated which was founded upon the influence of comets; and as we have tolerated the idea of an original conflagration of the earth, and its ſucceeding temperature.

"BURJA."

Letter from her Highneſs the Princeſs of Daſchkaw, Privy Counſellor to the Empreſs of all the Ruſſias, Preſident of the Imperial Academy of Sciences at Peterſburgh, Knight of the (Female) order of St. Catharine, &c.

SIR,

THE Contents of your letter, which we received with the encloſed Magnetic Atlas, and its explanation, in due time, were the more intereſting and agreeable to the Imperial Academy of Sciences, as the ſame matter is the ſubject of a Premium even now propoſed by our Academy, as you will ſee by the printed advertiſement I ſend you herewith.

THE progreſs you have already made gives me a pleaſant hope, this important matter will derive no ſmall increaſe from your ingenious works; and I make no doubt but your labours will greatly contribute to the final ſolution of this queſtion. By the communication of your further enquiries and diſcoveries, eſpecially relating to the ſouthern hemiſphere, the calculation of an univerſal ſet of tables, and the aſcertaining of the exact revolutions of the two magnetic points round the poles of the earth, by a greater number of obſervations, you will very much oblige your humble ſervant,

PRINCESS OF DASCHKAW.

St. Peterſburg, Feb. 27th 1791.
To Mr. John Churchman.

Extract of a Letter from the Royal Society of Copenhagen, dated March 15th, 1791.

"THE Society is obliged to Mr. Churchman for the communication of his elaborate treatiſe, and cannot but admire his genius, and praiſe the ſagacity with which he has built up a ſyſtem, wanting neither beauty nor ſymmetry. The attempt of Mr. Churchman to clear up this dark matter is very laudable, and cannot but meet with the approbation of the Natural Philoſopher.

"By order of the Society,

"CHRISTIAN FREDERICK JACOBI,

"Perpetual Secretary."

Extract from the Report made to the Honourable Patriotic Encouraging Society of Arts and Commerce, at Hamburgh, by its commiſsioned Members, dated March 16th, 1791.

"THE inveſtigations of an Euler, a Tobias Meyer, &c. &c. to ſolve this Problem, with all the additional improvements made ſince by other men of renown, with the help of Aſtronomy, muſt appear in a very indifferent light, compared with Mr. Churchman's eaſy mechanical method; for, whatever thoſe ingenious men have been able to collect, by their profound calculations and laborious obſervations, is now to be performed by a ſimple ſcale.

Signed, "BRODHAGEN

"REINKE."

Extract of a Letter from the Royal Academy of Liſbon, dated May 19th, 1791.

"THIS Royal Academy has received, by two different ways, nearly at the ſame time, your explanation of the Magnetic Atlas; commiſſion was inſtantly given to Gentlemen of the Profeſſion and Mathematicians, Members of the Society, to examine it accurately, and to bring in their advice in ſome of the ordinary academical meetings; this they have performed, and I am directed to ſend you, in this letter, the reſult of their examination and advice. They acknowledge the originality and uſefulneſs of your ideas and ſcheme, and that both highly deſerve to be encouraged. They believe indeed, that when the propoſitions you enunciate are demonſtrated, a great ſtep will be made towards the perfection of magnetic knowledge. Theſe demonſtrations they expect from you, and in the mean while they readily accept the invitation of giving you what magnetical obſervations it will be in their power to afford you. As, for my part, I am, with ſentiments of eſteem and reſpect, Sir,

"Your moſt obedient,
"Humble ſervant,
"JOSEPH CORREA de SERRA,
To Mr. John Churchman. "Secretary."

Extract of a Letter dated Cambridge, 5th March, 1792.

"Sir,

"YOUR late communications were preſented to the American Academy of Arts and Sciences, the 29th ultimo, and I am directed to return you the thanks of the Academy for the ſame.

"I have the pleaſure to aſſure you, that the Society is pleaſed with your application to the ſubject, and highly approves your very laudable deſign of improving magnetic obſervations. Convinced of the importance of aſcertaining, with accuracy, the magnetic variations in different parts of the globe, the Academy wiſhes you ſucceſs in your propoſed voyage; and that it may contribute towards perfecting a diſcovery highly uſeful to mankind. With ſentiments of due reſpect,

"I am Sir,
"Your obedient humble ſervant,
"ELIPHALET PEARSON,
To John Churchman, Eſq. "Correſponding Secretary."

Letter from General Waſhington, Preſident of the United States, on ſailing to Europe, dated Mount Vernon, September 10th, 1792.

Sir,

YOUR Letter of the 5th did not reach my hands until the 8th, and this is the firſt opportunity that I have had to give the receipt of it an acknowledgement.

I have encloſed you two ſhort letters of introduction to our Miniſters at the courts of Paris and London. I wiſh your voyage may anſwer your own expectations, and that the diſcovery may be beneficial to mankind, being, Sir, Your very humble ſervant,

G. WASHINGTON.

Mr. J. Churchman.

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SOME inconveniencies having arisen in the firſt and second editions of this work, from the method of finding the variation on the charts for any particular place, which operation was performed by measuring the angles between the true meridians and the magnetic meridians.

THE true meridian for any place being an arch of a great circle, and none of the magnetic meridians, except the firſt and the last being arches of great circles, the angles of variation could not always be truly measured without certain allowances not easily calculated with precision; a circumstance which has occasioned the principles of the former charts to be misunderstood by some individuals. To overcome this difficulty, and to render this new edition as simple and perfect as possible, dotted curve lines have been drawn through the different places where the variation is equal, thereby avoiding the trouble of measuring angles.

THE reader is respectfully informed, that the lines of equal variation on the charts, have been compared with the observations of the moſt celebrated modern circumnavigators; and the Editor muſt confess that there are some circumſtances, where two magnectic points alone are not sufficient to account for the extraordinary shape of the dotted curve lines which pass through the points of equal variation; nevertheless charts may be drawn on the same principles for any future time, which muſt ever continue to be of the greateſt utility in Geography and Navigation.

In the book a rule is laid down, for computing the revolutions of the magnetic points; yet, these cannot be calculated with precision, until their geographical situations are better determined by actual observations made in their respective latitudes.

The broken lines marked O shew where the magnetic needle stands due north and south, and divide the tracts of east and west variation. The dotted curve lines shew the variation of the compass, whether east or west, which is known by the numerical figures standing opposite to each one, but as their use may not appear evident to every person, it may be necessary to solve the following problems.

PROBLEM I.

Example I. A ship in the Atlantic Ocean, by a good observation, is in latitude 40° north, the variation of the compass is found to be 15° west, required the ship's place. Trace the dotted line numbered 15° until it intersects the latitude of 40° then turn to the equator, and see what degree of longitude passes over that place and it will be found to be the 38th.

Example II. In the southern hemisphere, the variation was found to be 20° west in the latitude of 29° 30′ south, what longitude is the ship in? The place of the ship will be found at H. in longitude 57° east.

PROBLEM II.

The latitude and longitude of a ship at sea given, required the variation of the compass.

Rule. Find the place of the ship on the chart, and observe what curve runs nearest that place; trace that curve to the numerical Index, and the variation is found.

Example. In latitude 35° north, and longitude 30° west, what is the variation? The intersection of that meridian and parallel will be at G. trace the curve passing nearest that place to the numerical index, and it directs to 18° which is west variation.

To find the variation by an azimuth, it is necessary to know the altitude and bearing of the sun at the same instant, but the motion of a ship at sea has been found to give a motion to the needle; to overcome this difficulty, the following method has been tried with success, which is nothing more than taking the mean of 20 bearings as fast as they can be read off. For example, on the 15th July, 1796, the sextant was set to 11° & 12°, and one half of the bearings were taken before and the other half just after the sun came to the horizon, the mean when 11. is N. 74° 36′ E. by compass, which is the magnetic azimuth.

sun's alt.			
°	°	° ′ ° ° ′	° ′ ° ° ′
11	12	90 90 90	90 90 90
		lat. 38 58 alt. 11 dec. 21 24	lat. 38 58 alt. 12 dec. 21 24
75	76		
73	76	79 pol dis. 68 36	co alt. 78 pol. dis. 68 36
74	75	co lat. 51 2 ar. co-s. .10929*	co lat. 51 2 ar. co-s. .10929
75	75	co alt. 79 ar. co-s. .00805	co alt. 78 ar. co-s. .00960
75	75	pol dis. 68 36	pol dis. 68 36
74	75		
75	75	sum 198 38	sum 197 38
75	75		
74	75	½ do. 99 19 log. s. 9.99423†	½ do. 98 49 l. s. 9.99484
76	76	68 36	68 36
76	75	rem. 30 43 log. s. 9.70824	rem. 30 13 l. s. 9.70180
75	75		
74	75	19.81981	19.81553
74	76	35° 38′ 9.90990	36° 2′ 9.90776
74	75	2	2
75	76		
75	75	71 16 true az.	72 4 true. az.
74	76	74 36 mag. az.	75 18 mag. az.
75	75		
74	75	diff. 3° 20′ variation.	diff. 3° 14′ variation.
20)1492	1506	sum of bearings	
74° 36′	75° 18′	mean.	

---

* The co secant rejecting the index.

† The ½ sum, being above 90° it is subtracted from 180, and the logarithm sine of the remainder is taken.

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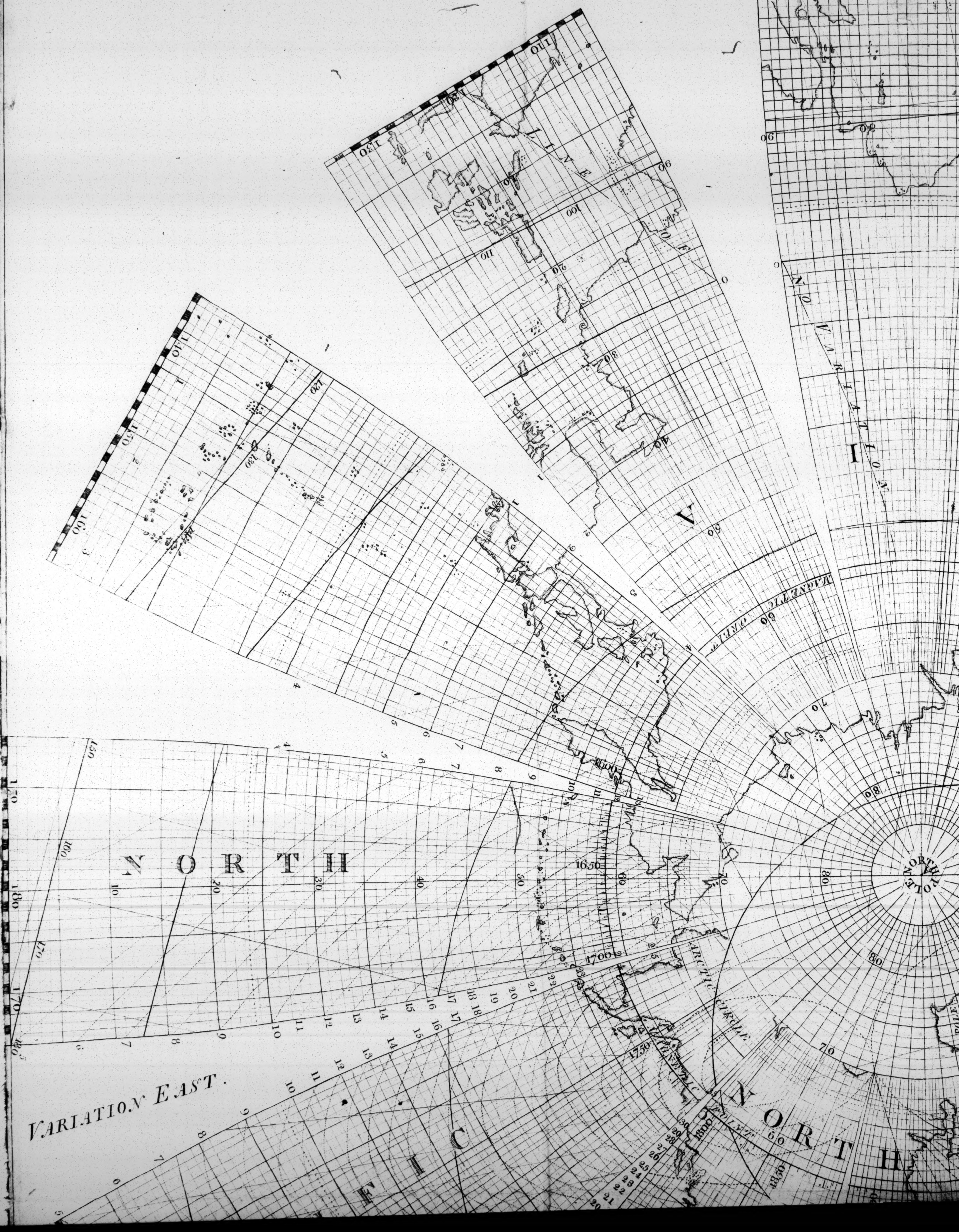
11

PLATE I.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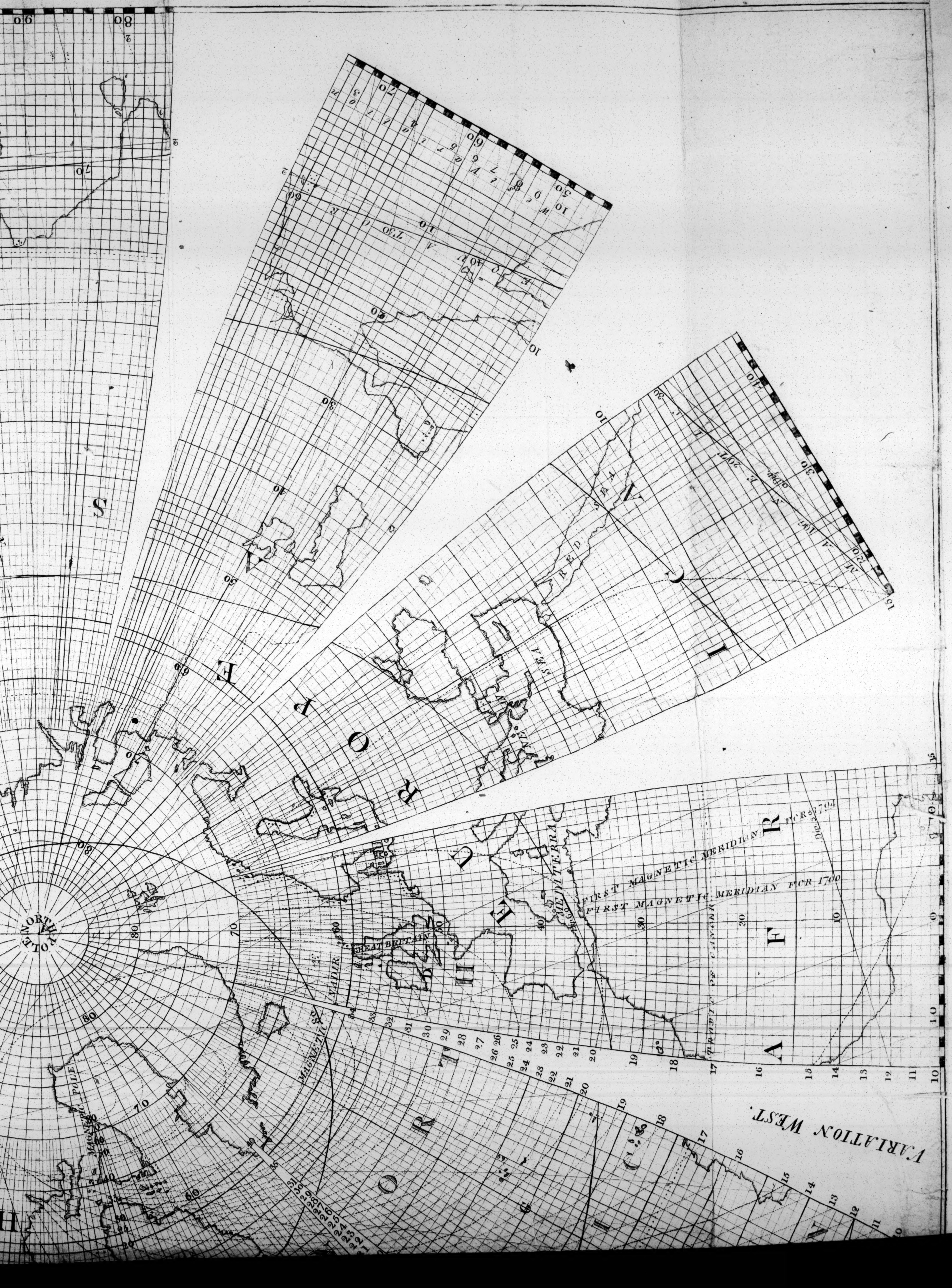
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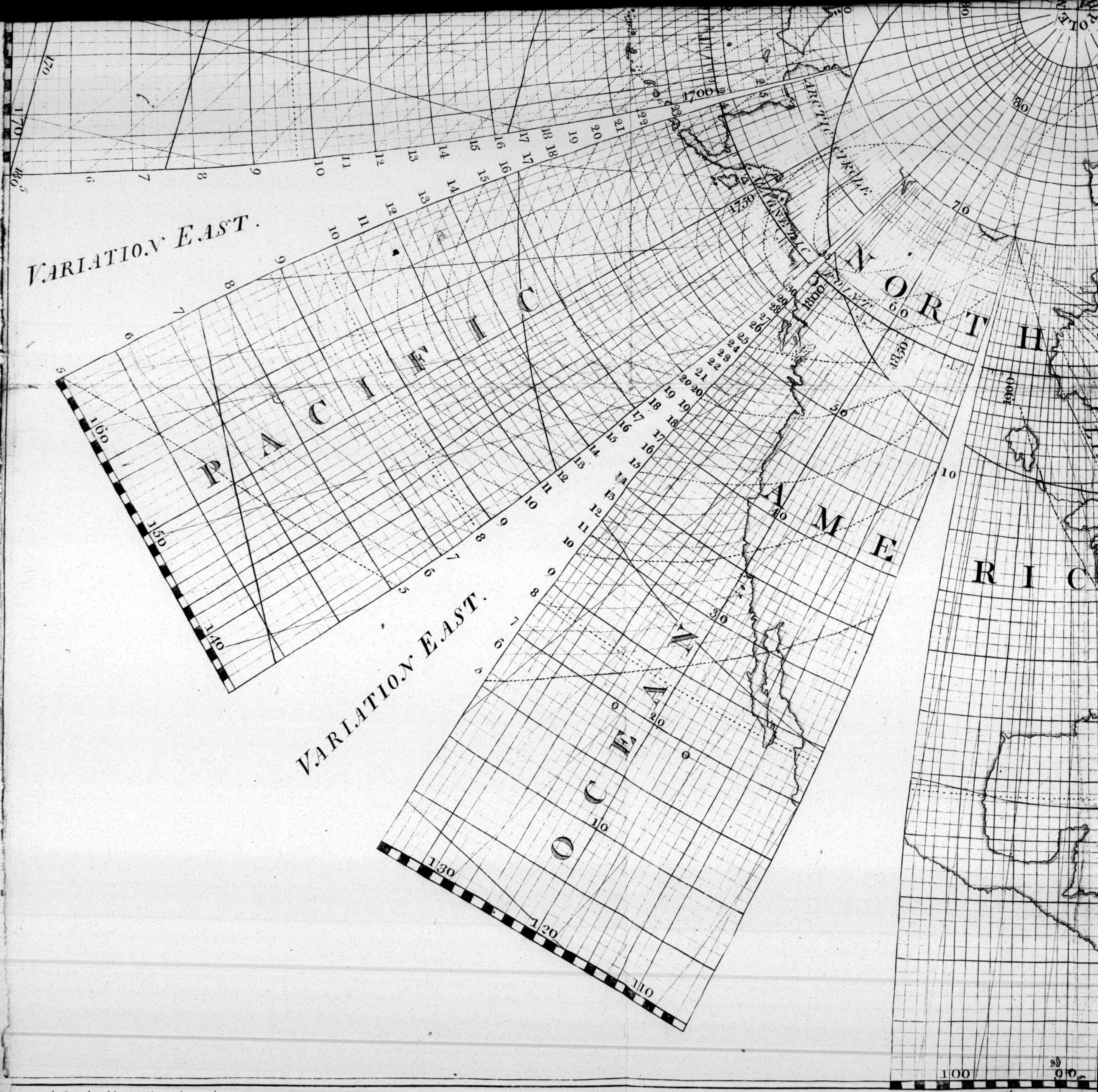

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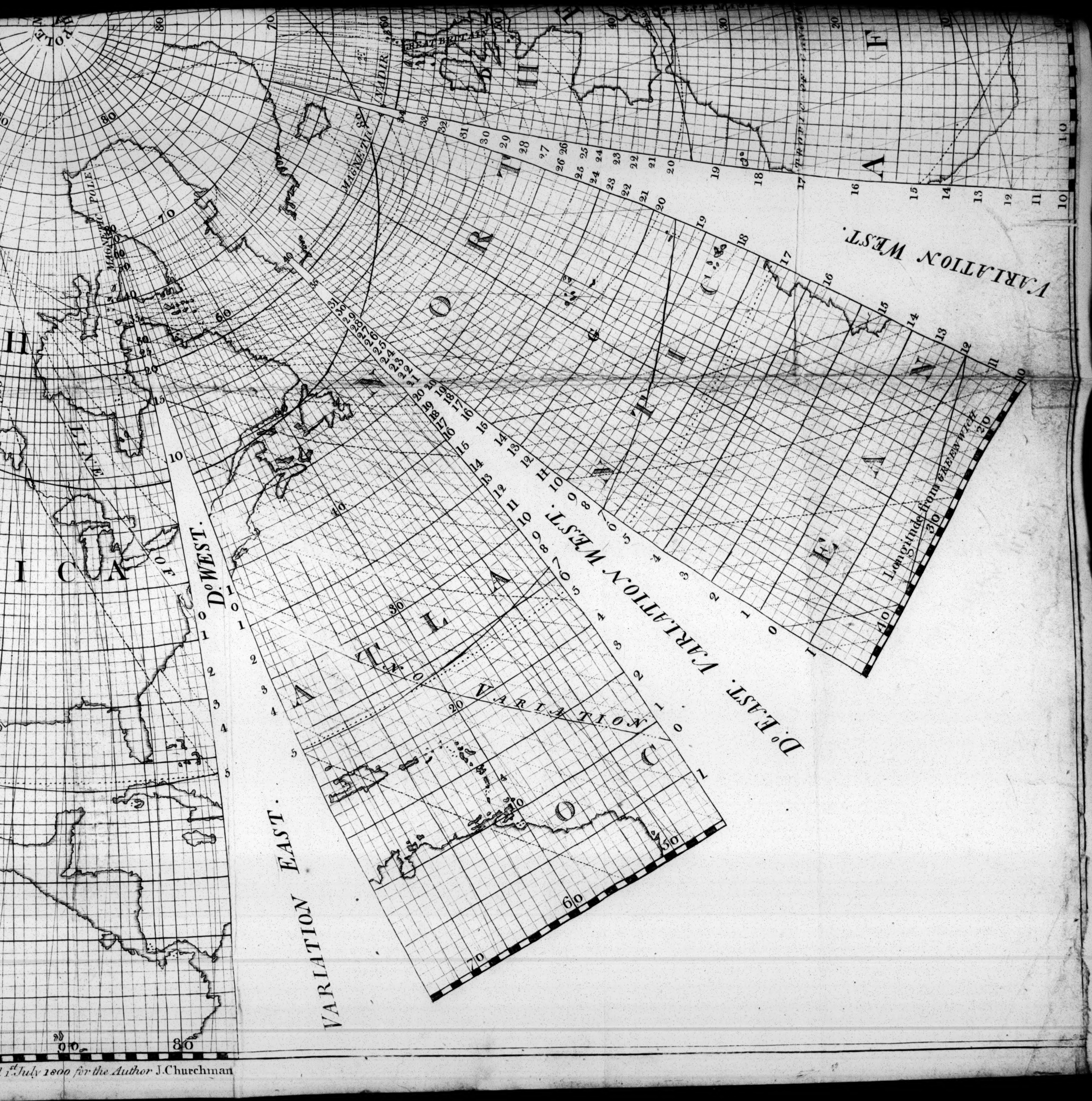

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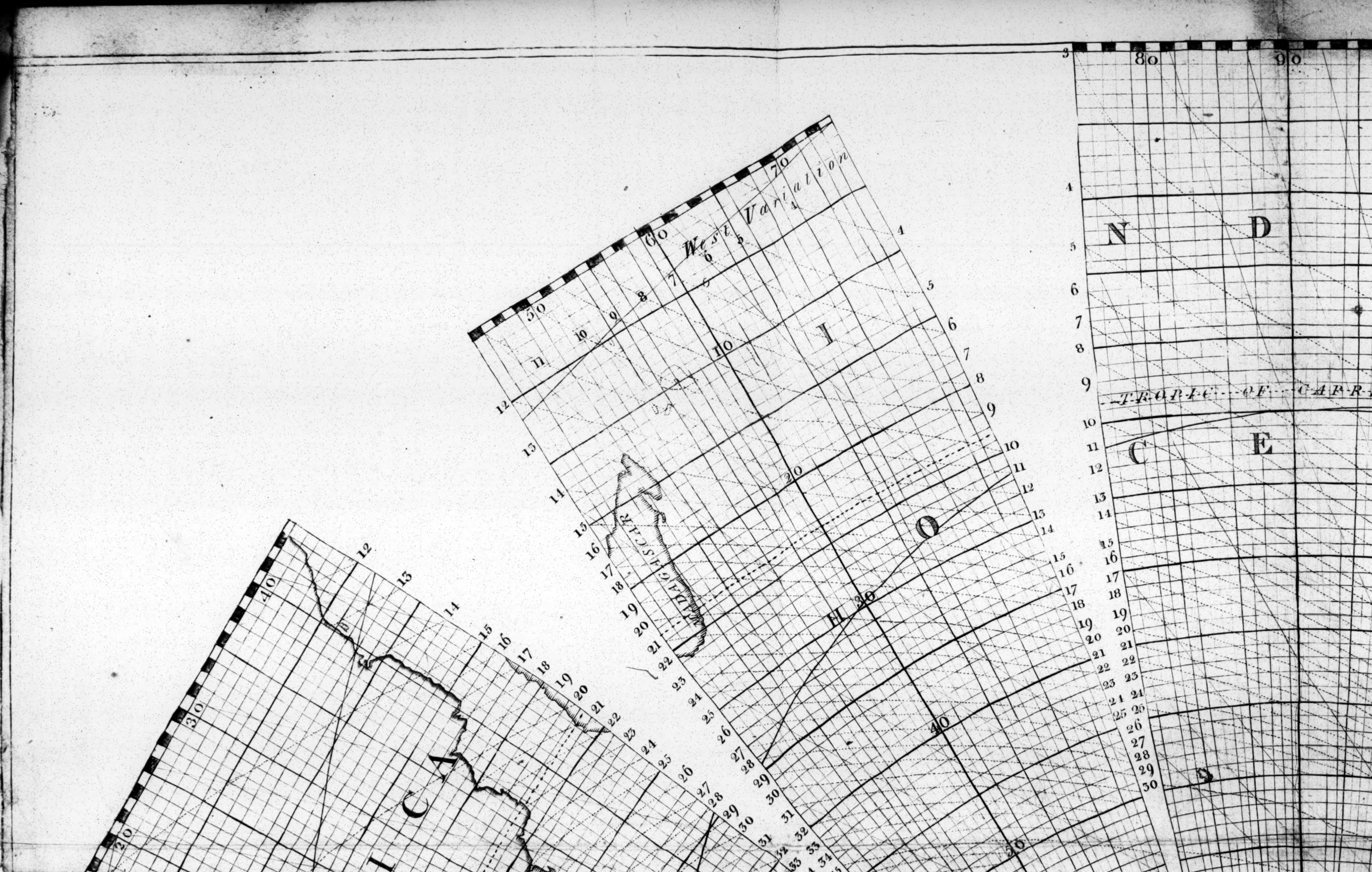
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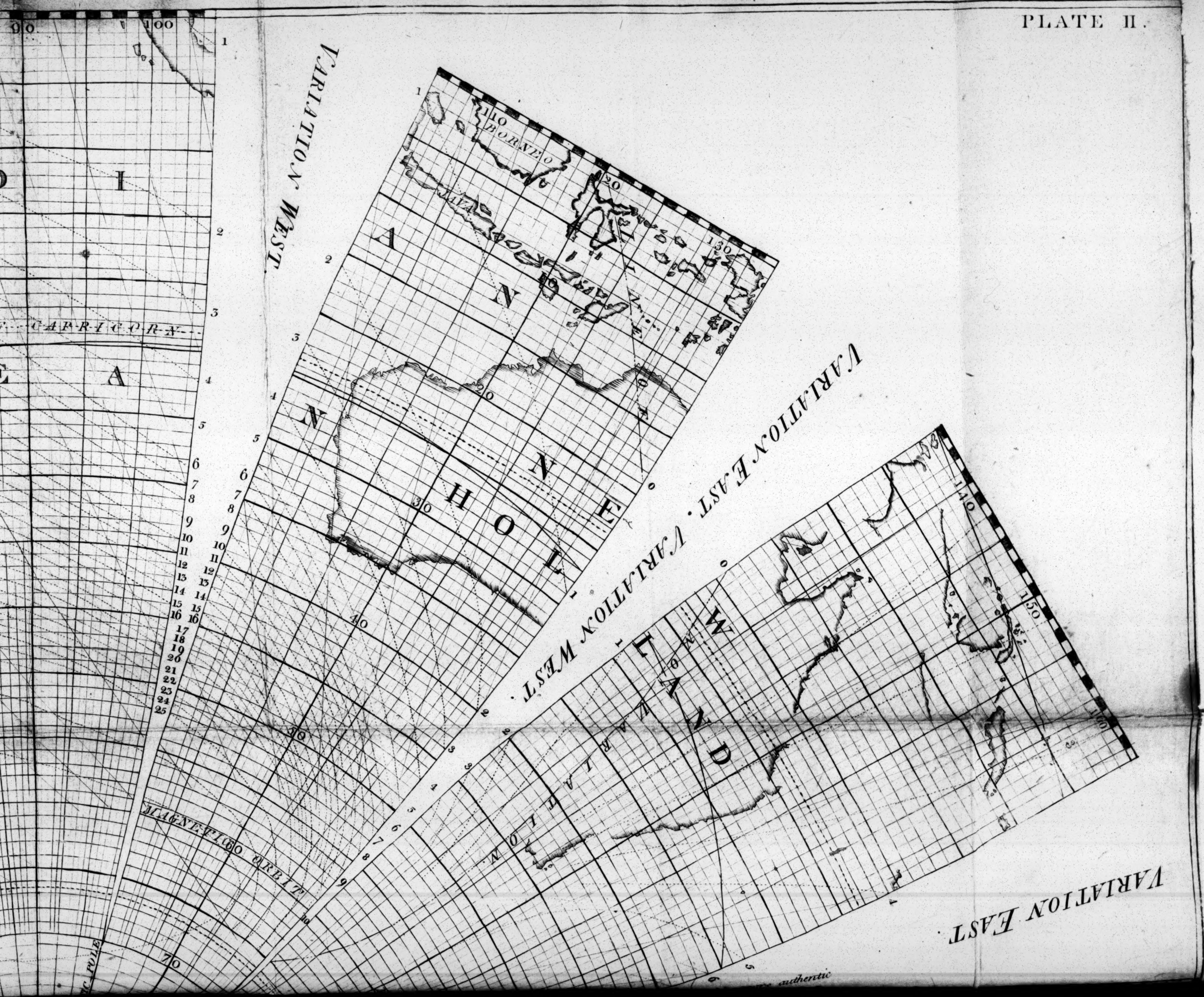
PLATE II.



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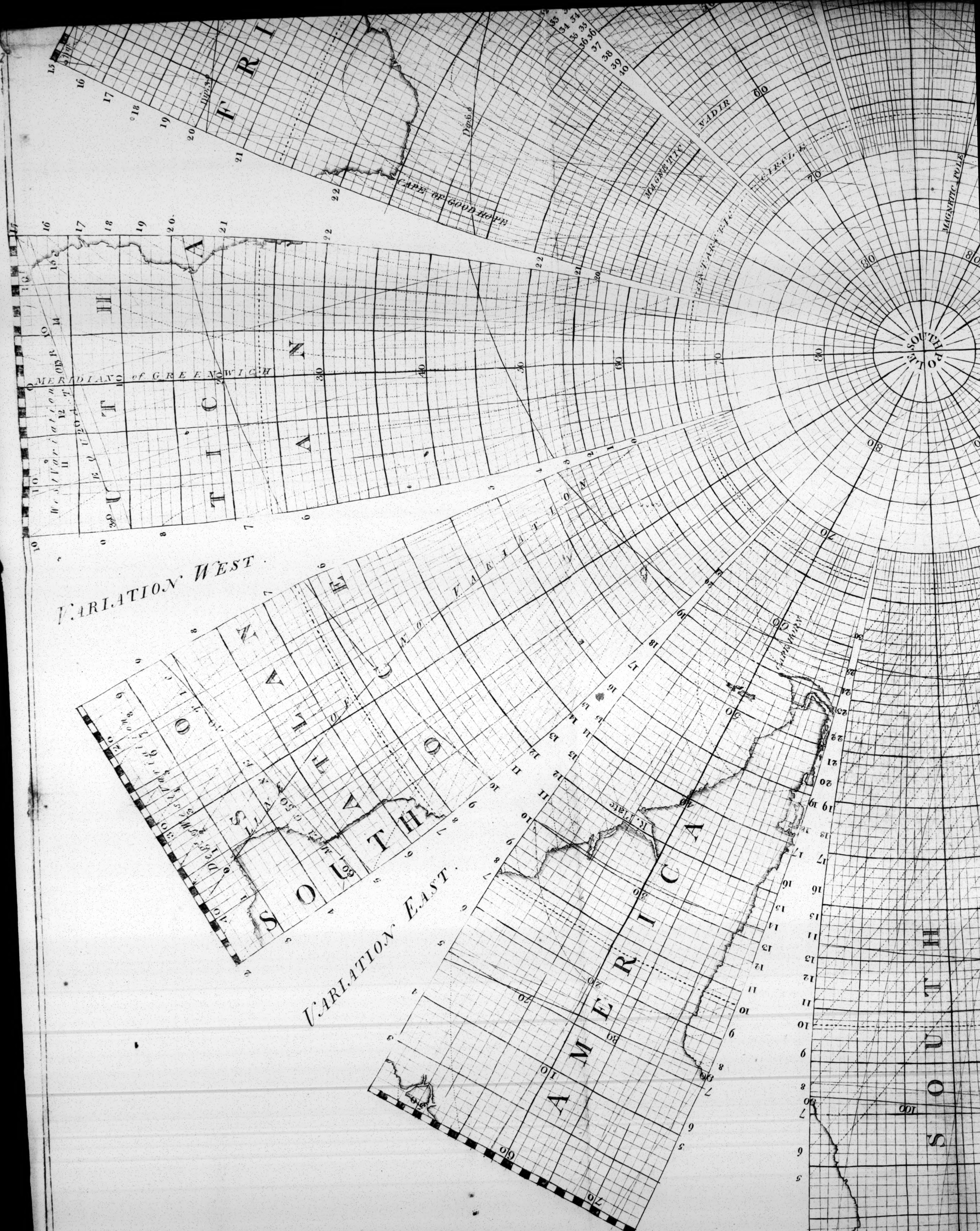

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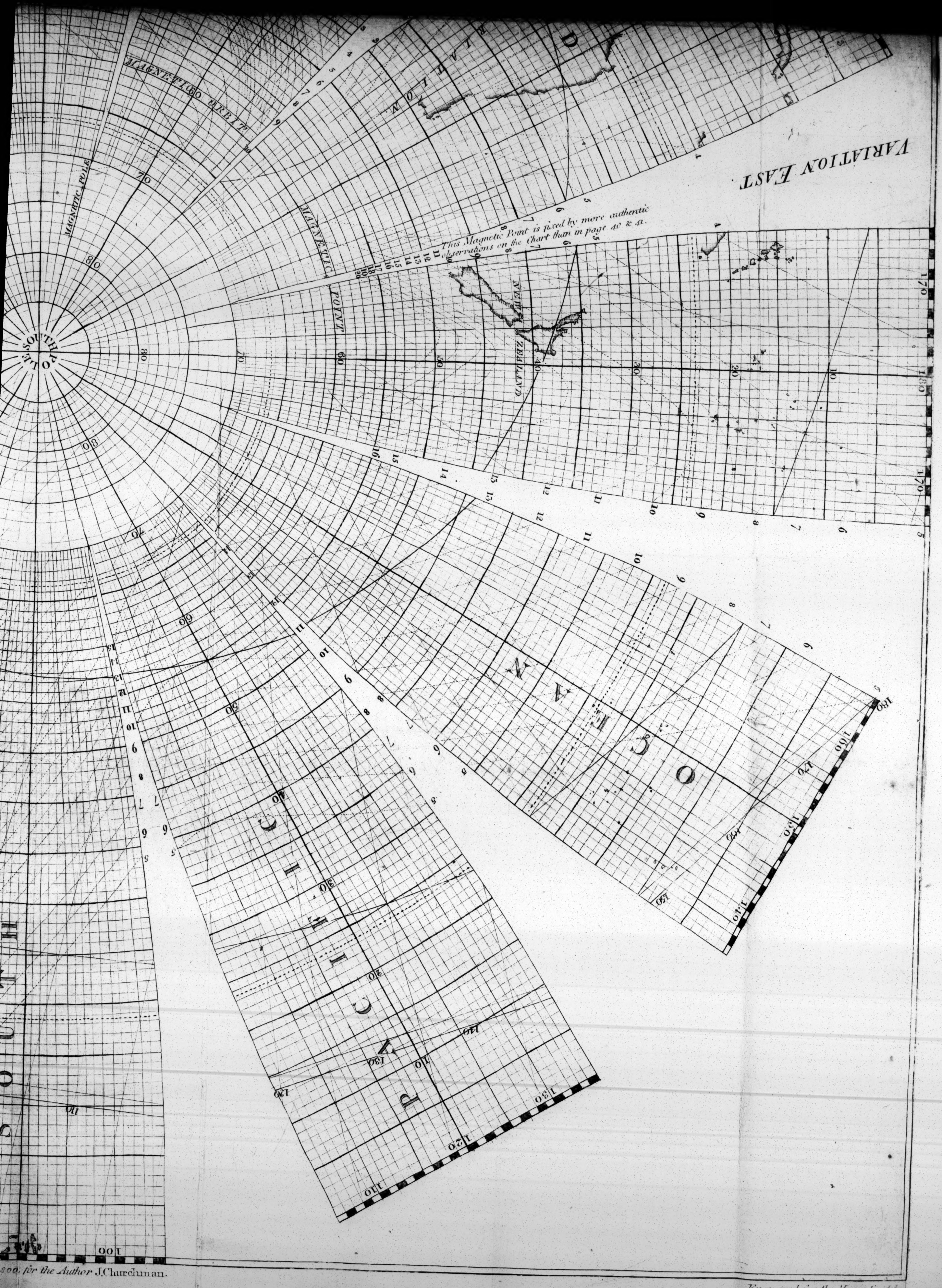

This Magnetic Point is fixed by more authentic observations on the Chart than in page 40 & 41.

800, for the Author J.Churchman.

Engraved for the Magnetic Atlas

Fig. II.

A STEREOGR

PROJECTION of the
on the Plane of
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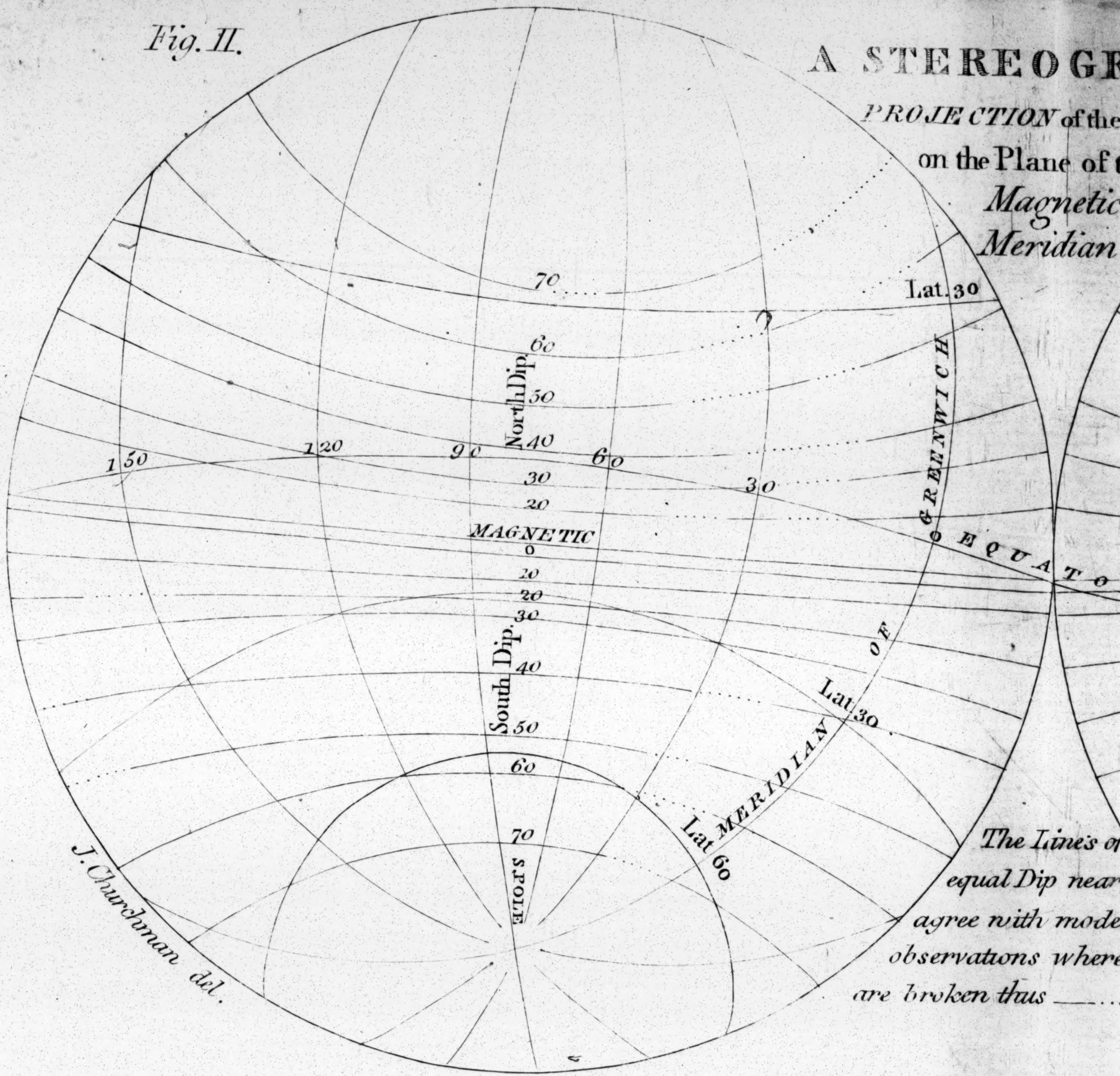

J. Churchman del.

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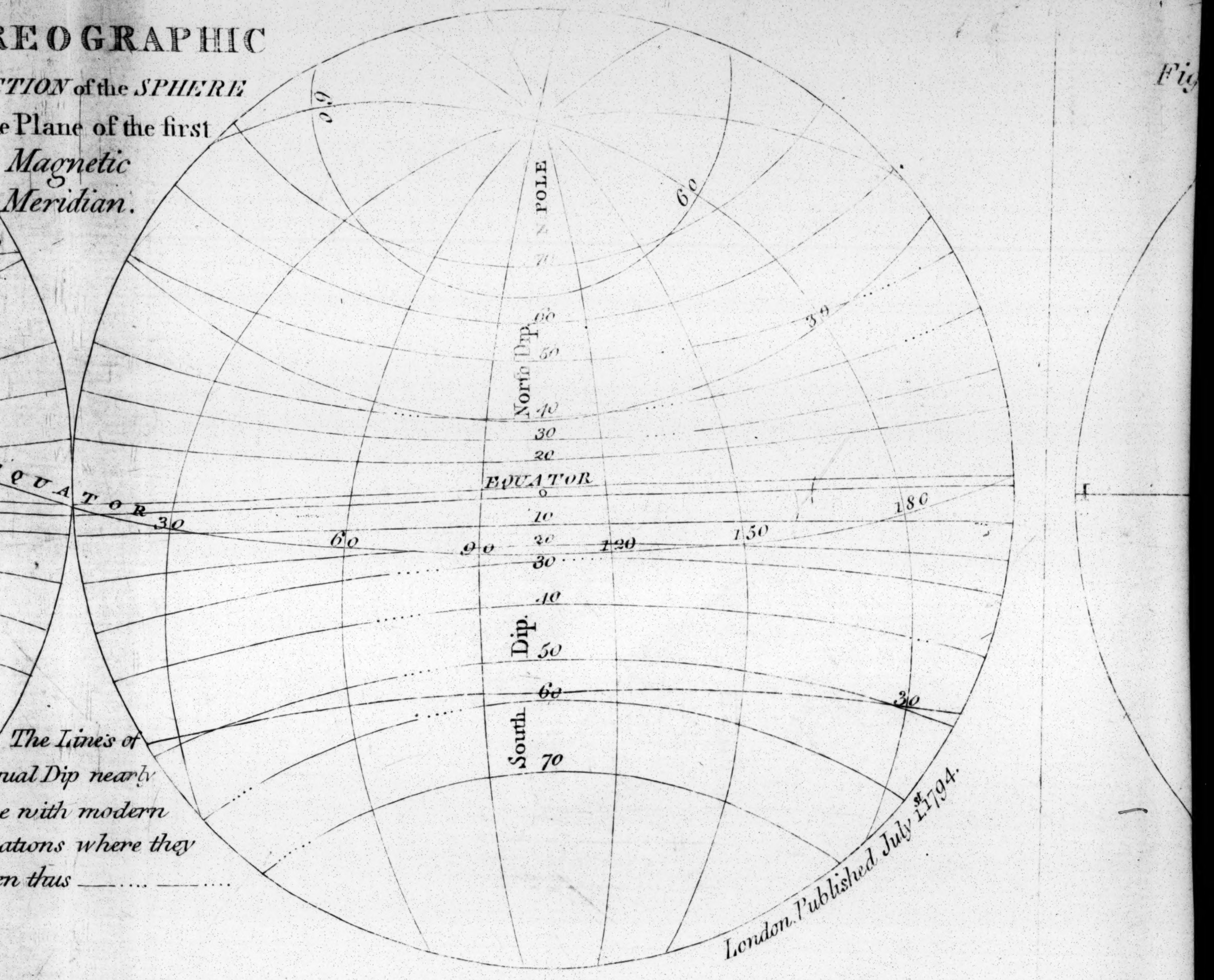

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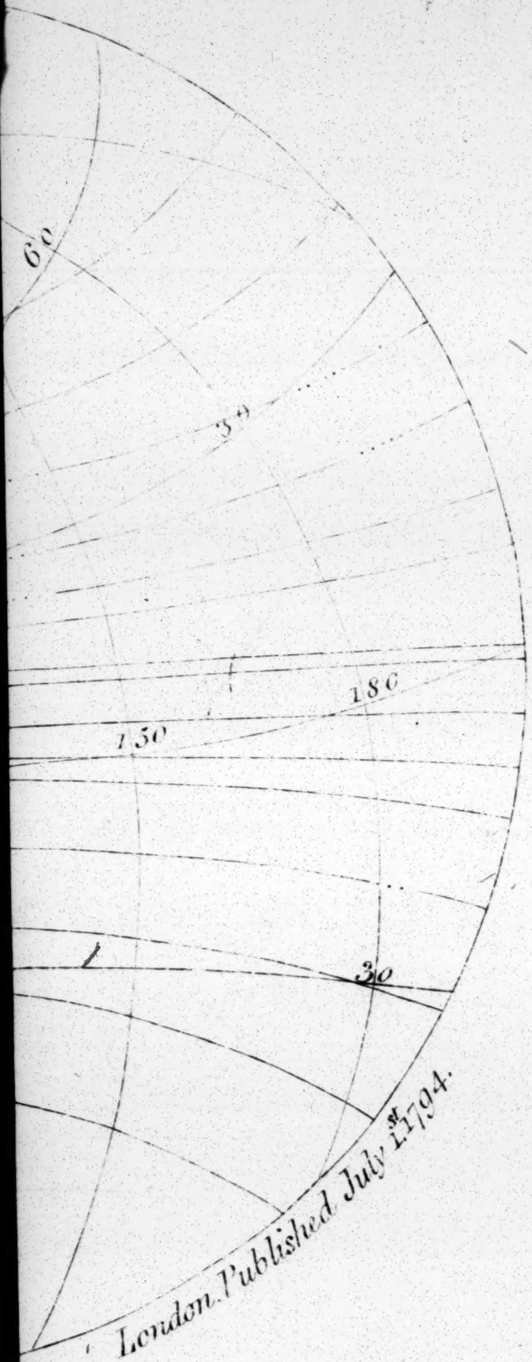
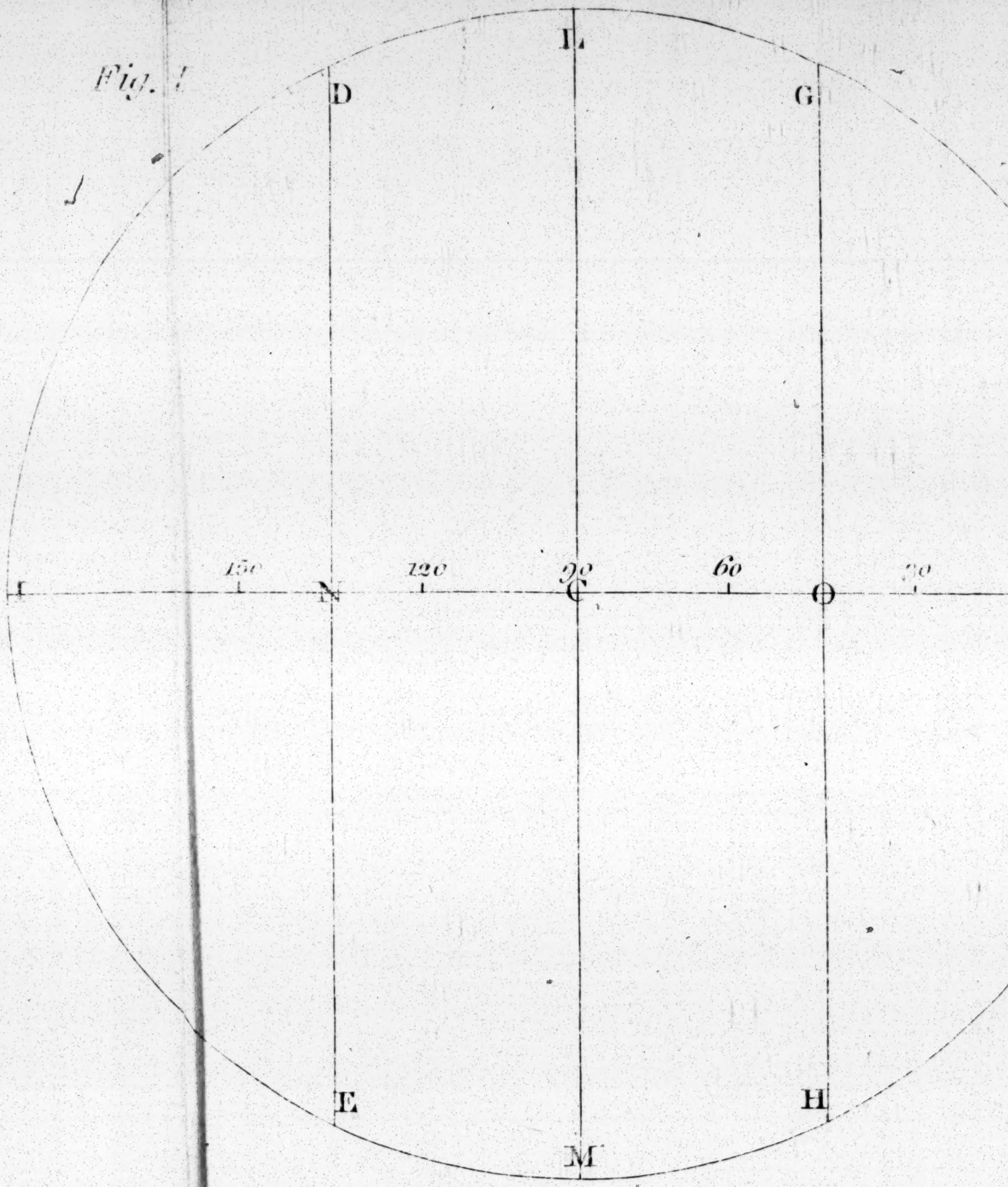
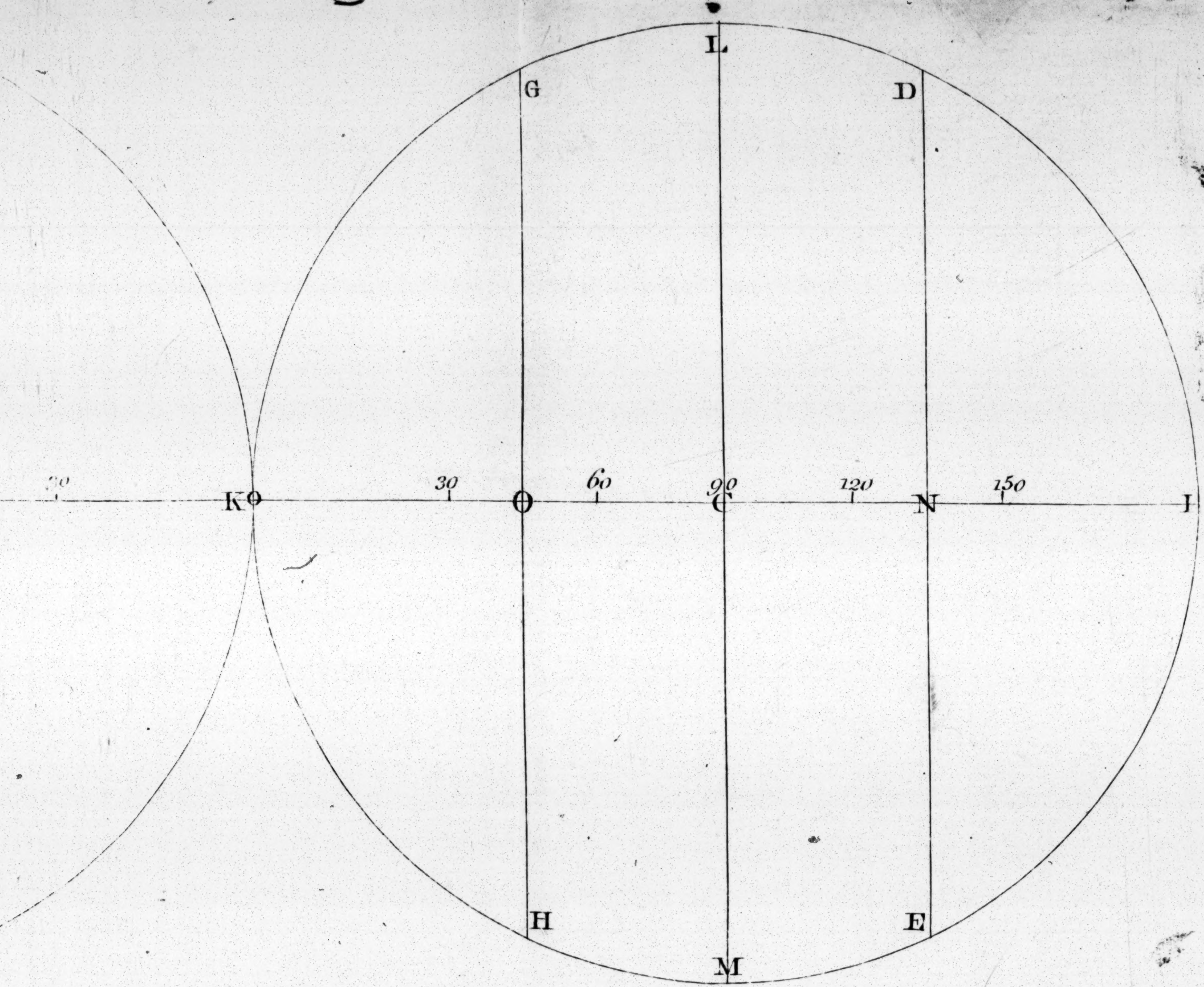
London. Published July 1st 1794.



London. Published July 1st 1794.

Fig. 1

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